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ARENACEOUS FORAMINIFERA FROM HASLER FORMATION, NORTHEASTERN BRITISH COLUMBIA

by

© KORY R. KOKE

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled ARENACEOUS FORAMINIFERA FROM HASLER FORMATION, NORTHEASTERN BRITISH COLUMBIA submitted by KORY R. KOKE in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

Fifty-three species and subspecies of Foraminifera recovered from the Hasler Formation on the Peace and Pine Rivers in northeastern British Columbia are figured and described. The benthonic assemblages contain: _Bathysiphon_ (2 species), _Hippocrepina_ (2), _Hyperammina_ (1), _Psammosphaera_ (1), _Saccammina_ (2), _Thuramminoides_ (1), _Ammodiscus_ (2), _Glomospira_ (1), _Reophax_ (1), _Miliammina_ (4), _Psamminopelta_ (1), _Haplophragmoides_ (7), _Trochamminoides_ (1), _Ammobaculites_ (7), _Ammomarginulina_ (1), _Haplophragmium_ (2), _Pseudobolivina_ (1), _Plectorecurvoides_ (1), _Trochammina_ (6), _Verneuilina_ (1), _Gaudryina_ (1), _Uvigerinammina_ (1), _Verneuilinoides_ (1), _Arenobulimina_ (1), and _Gravellina_ (3).

Three sections represent the lower part of the _Miliammina manitobensis_ Zone, the upper part of the _Haplophragmoides gigas_ Zone, and the _Ammobaculites wenonahae_ Subzone, all important stratigraphic markers in western Canada. These suites indicate Arctic connections and give evidence of the Joli Fou sea occurring north of the Peace River Arch. _Haplophragmoides gigas_ is probably a boreal form with possible ancestors in the Middle Albian of Alaska.

Studies on living foraminifers indicate that size variations in the _Haplophragmoides gigas_ assemblage may be related to stress conditions resulting in gigantism. In foraminifers, size variations should not be a primary factor

in specific assignments.

All samples examined lack calcareous foraminifers. This condition probably represents a low pH of the waters (or sediment), or an extremely shallow carbonate compensation depth. It is also possible that some unknown environmental factor prevented calcareous forms from colonizing Middle and Upper Albian seas in northeastern British Columbia.

ACKNOWLEDGEMENTS

Dr. C. R. Stelck of the University of Alberta suggested the topic of this thesis and served as supervisor. He also supplied many of the samples and lots of encouragement.

Special thanks are also due to Dr. G. D. Williams, Dr. B. D. E. Chatterton and Mr. A. Hedinger, who supplied technical advice and assistance. Heidi Solanki, Barbara Neilsen, and Kathy Johnson washed and picked many of the samples. Robin Turner helped with the diagrams.

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CHAPTER 1

INTRODUCTION

This thesis is a biostratigraphic study of Foraminifera occurring between the ammonite zones of *Gastroplites* and *Neogastroplites* (zonation of Jeletzky, 1968) in Albian rocks of northeastern British Columbia. Many sections and spot samples of shale were analyzed for their microfaunal content and, of these, 3 critical sections were selected. One sampled section is in the Hasler Formation on Hasler Creek in the Pine River area. The other two are from the lower Shaftesbury (Hasler) Formation on the Peace River: one in the vicinity of Halfway River, and the other about 32km downstream from Hudson Hope (fig. 1B).

Hypothesis

The topic of this thesis was suggested by Dr. Charles Stelck. He postulated the existence in northeastern British Columbia of a microfauna equivalent to the *Haplophragmoides gigas* assemblage of the interior plains. From 1946 for a decade when western Canadian micropaleontology experienced its first application to stratigraphic problems, a number of microfaunal zones based on arenaceous foraminifera were described. The *H. gigas* Zone, characteristic of the Joli Fou and Ashville Formations of the plains, was not extended beyond Peace River (town) into British Columbia.

This is not surprising, perhaps, when one considers the immense thicknesses of Albian black shales that outcrop in northeastern British Columbia from the Peace country to the Liard River. Marker horizons are uncommon, and the true thicknesses and dispositions of such formations as the Hasler, Buckinghorse, and Garbutt have yet to be worked out in detail. Megafossils are rare, and any ammonites recovered are poorly preserved. In some intervals, ammonite control is almost entirely absent.

In view of these difficulties, the discovery in the area of a distinctive biostratigraphic marker would give geologists a convenient reference point. This thesis is the first description of the equivalents of the H. gigas fauna in northeastern British Columbia. Sections above and below the H. gigas-bearing section were also studied to obtain some continuity with the upper and lower transitions to H. gigas zonal species.

As is the case with most studies of this type, some intriguing new questions are raised. Does Halophragmoides gigas range north to the Sikanni Chief, Buckinghorse, and Liard drainages? Preliminary evidence (see especially Tappan, 1962, pl. 30, fig. 15) indicates that its immediate ancestors probably occur as far north as Alaska. It is likely that this form is truly boreal, and that it has its roots in an Albian Arctic sea.

Historical review

The first geological expedition into northeastern British Columbia was headed by A. R. C. Selwyn in 1875. Later, in 1879, G. M. Dawson and R. G. McConnell traversed the study area en route from the Pacific ocean to Edmonton. These earliest explorers laid the groundwork for later workers, most of whom were involved in the search for coal or hydrocarbons, or were officers of the Geological Survey of Canada. The works of F. H. McLearn (1932, 1937, 1944a) McLearn and Kindle (1950), the Alberta Study Group (1954), Rudkin (1964), Irish (1965), and Stott (1968) are particularly relevant to the stratigraphy of this area.

Paleontological studies in this area were initiated by Whiteaves on material collected by Selwyn, Dawson, and McConnell (Whiteaves, 1893). Later work by McLearn (supra.) in the first half of the twentieth century described much of the known megafaunas of the region. In 1956 Stelck et al. synthesized mega- and microfaunal zonations for the region. Ammonite zonations were later refined by Warren and Stelck (1958, 1969), Reeside and Cobban (1960), and Jeletzky (1968).

Study area and access

This thesis concerns itself primarily with Albian rocks of the Hasler Formation and the lower Shaftesbury Formation in northeastern British Columbia. The study sections are located on the Peace and Pine River drainages in the Hudson Hope--Chetwynd area of British Columbia (figs. 1A, B).

Today, much of the area is readily accessible by good roads. Seismic lines and rivers provide access to large areas for the appropriate vehicles. For difficult to reach spots, helicopters can be based out of Hudson Hope, Chetwynd, or Ft. St. John.

METHOD OF STUDY

Field work

Three sections sampled for microfossils were included in this study. The lowest stratigraphically, the "Farrel" section, is from the mouth of a small creek entering the Peace River about 7km upstream from its confluence with the Halfway River. The middle section, named "Attachie" after a nearby hamlet, is located on the Peace River about 3km downstream from the mouth of the Halfway River. The third and stratigraphically the highest section, the "Hasler" sequence, is named after Hasler Creek, a tributary of Pine River. This locality is about 5.5km south of its confluence with the Pine River. See figure 1B for localities and place

names.

The "Farrel" section was collected by Dr. C. Stelck in 1951 while he was consulting for Pacific Petroleums Ltd. The author collected the "Attachie" section in the Autumn of 1977. Dr. C. Stelck collected the "Hasler" section in 1947 while employed by Imperial Oil Ltd.

Treatment of Samples

Samples were collected from predominantly argillaceous outcrops along watercourses (see Appendix A for sample lithologies). It was necessary to dig 20-30 cm into the outcrop to ensure that only fresh material was bagged. This method of spot sampling was used at a frequency of 1 sample for every 1-2m of section logged.

The "Attachie" samples were prepared by the writer in the fall and winter of 1977-78. 250 grams of shale from each sample was weighed into a sealed glass container and covered with water. In a period of time ranging from 2 weeks to 4 months, 20% of more of the shale had disintegrated sufficiently to be washed through standard Tyler screens (mesh sizes were 60, 80, 100, and 200). Silty or sandy shales require longer periods of time for disintegration; very soft black shales appear to hydrate to clay in only about 2 weeks. After washing, the material retained on each screen was dried and picked for Foraminifera. Samples

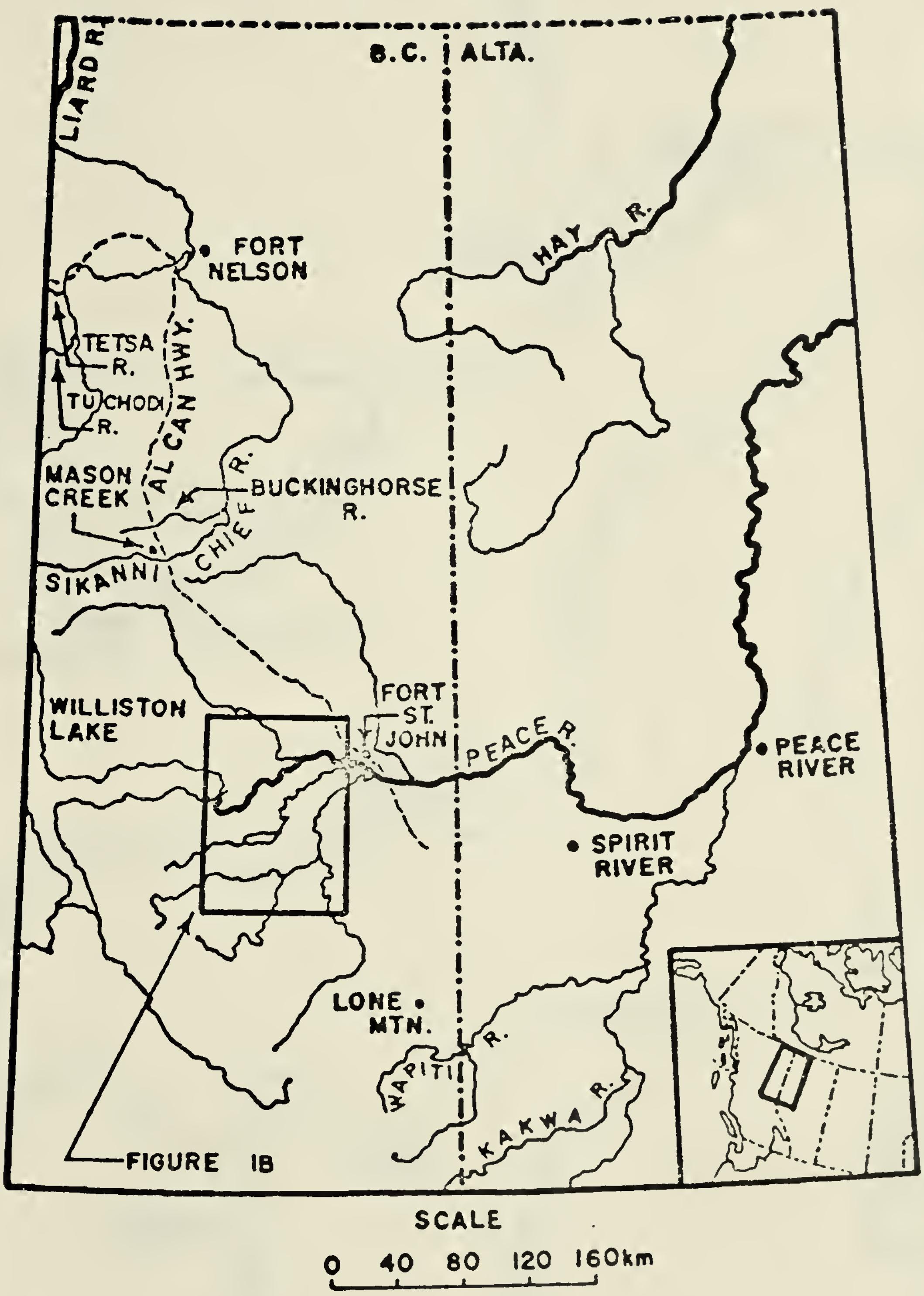

Figure 1A Location of study area.

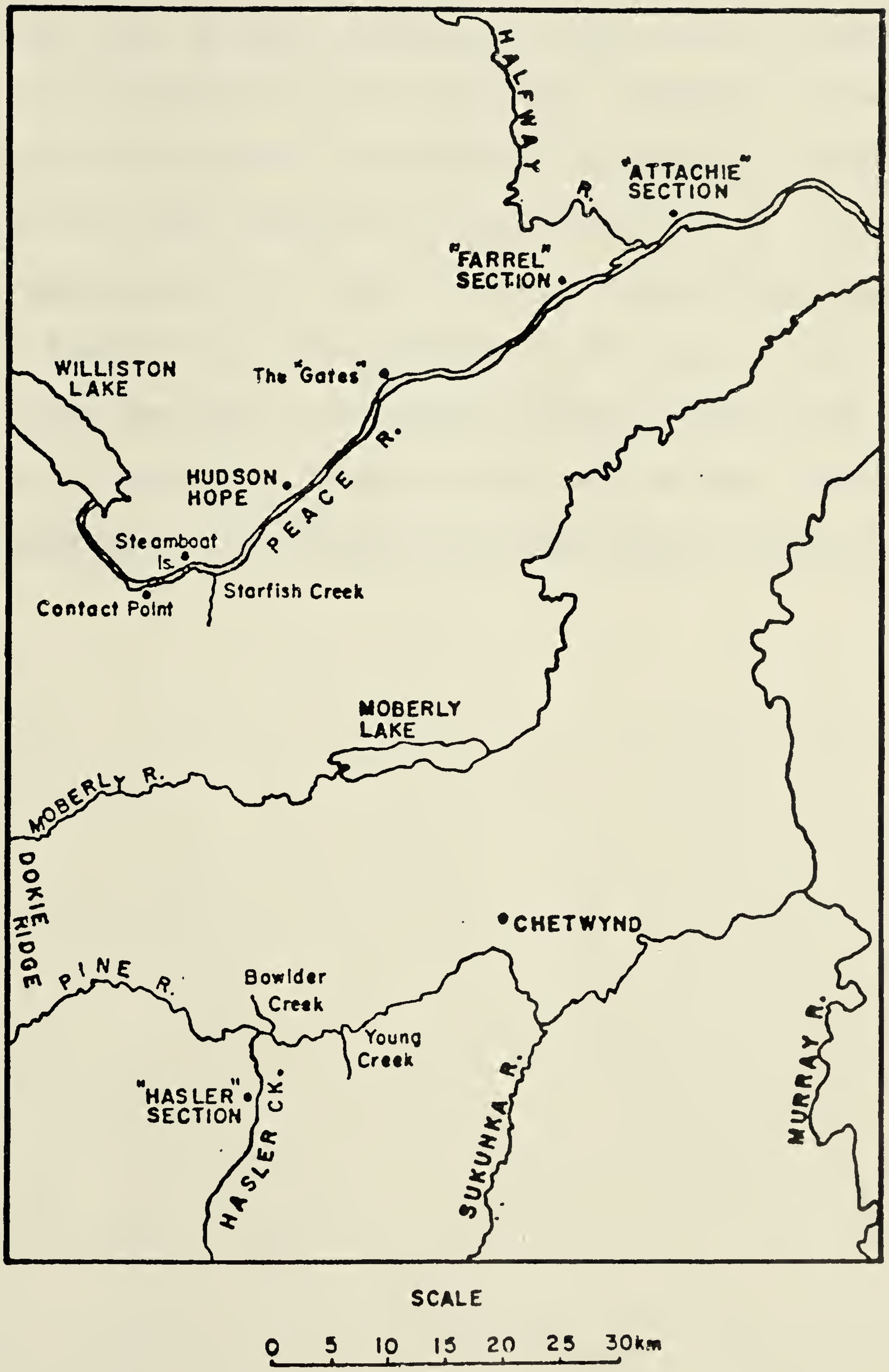

Figure 1B Study area in northeastern British Columbia showing locations of the "Hasler", "Attachie", and "Farrel" sections.

containing foraminifera with adhering shale were boiled with detergent to remove this material.

Cleaned and picked specimens were then classified according to Loeblich and Tappan's (1964) taxonomy. Statistical information was obtained by simply counting or estimating the total number of foraminifers on a slide or picking tray (a grid was used for estimations when counting was impractical). A few specimens of each taxon were then measured with the aid of a camera lucida; a small and large representative specimen of each group was always included. The specimens were illustrated with the camera lucida.

CHAPTER TWO

THE CRETACEOUS SYSTEM IN WESTERN NORTH AMERICA

The Lower Cretaceous sands and shales of northeastern British Columbia constitute only a local expression of a continent-wide phenomenon. The Cretaceous Period was dominated by successive floodings of large parts of North America. These epicontinental seas moved into the interior from the Pacific region, from the Arctic, and from what is now the Gulf of Mexico. Generally shallow to moderately deep (less than 2000m), these seaways shifted incessantly, creating the complex patterns of sedimentation that we see today.

Recurrent flooding during middle and upper Cretaceous times took place in the western Canadian-American epicontinental seaway. The waters filled a prominent north-south trending trough east of the developing cordillera. This region, roughly co-incident with the Great Plains physiographic belt, was rarely completely emergent. Usually, it was partially or wholly flooded by Gulfian (from the south) and Boreal (Arctic) transgressions that often coalesced to form a continuous seaway.

It is therefore no surprise that this trough, which carried extra fill to the west, was the locus of much of Cretaceous sedimentation in North America. Detritus was derived from the many mountain building events of the

western cordillera. This source was often supplemented by an eastern provenance synonymous in Canada with the Precambrian Shield. In addition to detrital material, carbonate sediments form important chalks and limy shales, especially in the United States. The net result of these events was the development of a relatively thick Cretaceous section, particularly in Canada. The condensed sections of the type European Cretaceous are much thinner by comparison. For example, the Fort St. John Group ranges in thickness from about 1500m in the Peace River Area (British Columbia) to about 2000m near Liard River (Stott, 1975). The type Gault Clay succession, a European equivalent of the entire Fort St. John Group, is a mere 43m thick at Copt Point, Folkstone, Kent, England (Hart, 1973).

CRETACEOUS ROCKS IN NORTHEASTERN BRITISH COLUMBIA

Cretaceous sedimentation in northeastern British Columbia follows the general pattern for that of the western interior of North America. Here, detritus derived from the rising Columbian Orogen to the west was deposited to the east in the western Canadian sedimentary basin, a northern segment of the North American epicontinental seaway.

Tectonic movements of the Columbian Orogen combined with subsidence in Alberta and notheastern British Columbia to produce a complex sequence of sands, shales, and conglomerates in northeastern British Columbia. This

enormous wedge-shaped mass of Cretaceous rock attains a maximum thickness of about 8500m in the western part. Stott (1975) divided these sediments into 3 major eastward thinning clastic cycles, each representing a broad transgressive-regressive sequence. The oldest one, containing rocks dating from Sinemurian to Valanginian, is composed of black shales of the Fernie Formation overlain by coarser clastics of the Minnes Group. The middle sequence, with sediments dating from Aptian to early Cenomanian, consists of the upper Bullhead and Fort St. John Groups and Dunvegan Formation. The uppermost clastic wedge represents rocks from Cenomanian up to Maestrichtian age and is formed by the Smoky Group and Wapiti Formation.

General Stratigraphy

This thesis is primarily concerned with rocks of Stott's (1975) second Cretaceous sequence (the Fort St. John Group in particular), and accordingly, a review of these rocks is presented here. The stratigraphic nomenclature followed is primarily that of Stott (1968). The contributions of the Alberta Study Group (1954) and McLearn and Kindle (1950) to the Cretaceous stratigraphy of northeastern British Columbia are related to Stott's framework (fig. 2).

Bullhead Group

The second transgressive-regressive cycle defined by Stott (1975) is underlain by an unconformity that probably represents (in northeastern British Columbia) the most profound break in Cretaceous sedimentation. The Neocomian sea receded to the north and west, leaving the whole of northeastern British Columbia exposed to erosion. Although sedimentation was interrupted for only a (relatively) short time span in the southwest part of the region, this unconformity separates strata of the Fort St. John Group from Triassic sediments in the Fort Nelson area. Farther to the north and east, Lower Cretaceous beds rest directly on Misissippian strata.

The basal formation of the upper Bullhead Group is the Cadomin Formation, present in the Alberta and British Columbia foothills as far north as Lake Williston, and as far south as Blairmore, Alberta (Mellon, 1967). It is composed of conglomerate and conglomeratic sandstones with phenoclasts of varicolored cherts, quartzite, and quartz. The thickness varies from 5 or 10m over most of western Alberta to about 200m near the Peace River in British Columbia. The upper contact is taken as the uppermost conglomeratic bed (Stott, 1973) and is thus transitional with the overlying Gething Formation.

The sequence of cherty to quartzose and carbonaceous

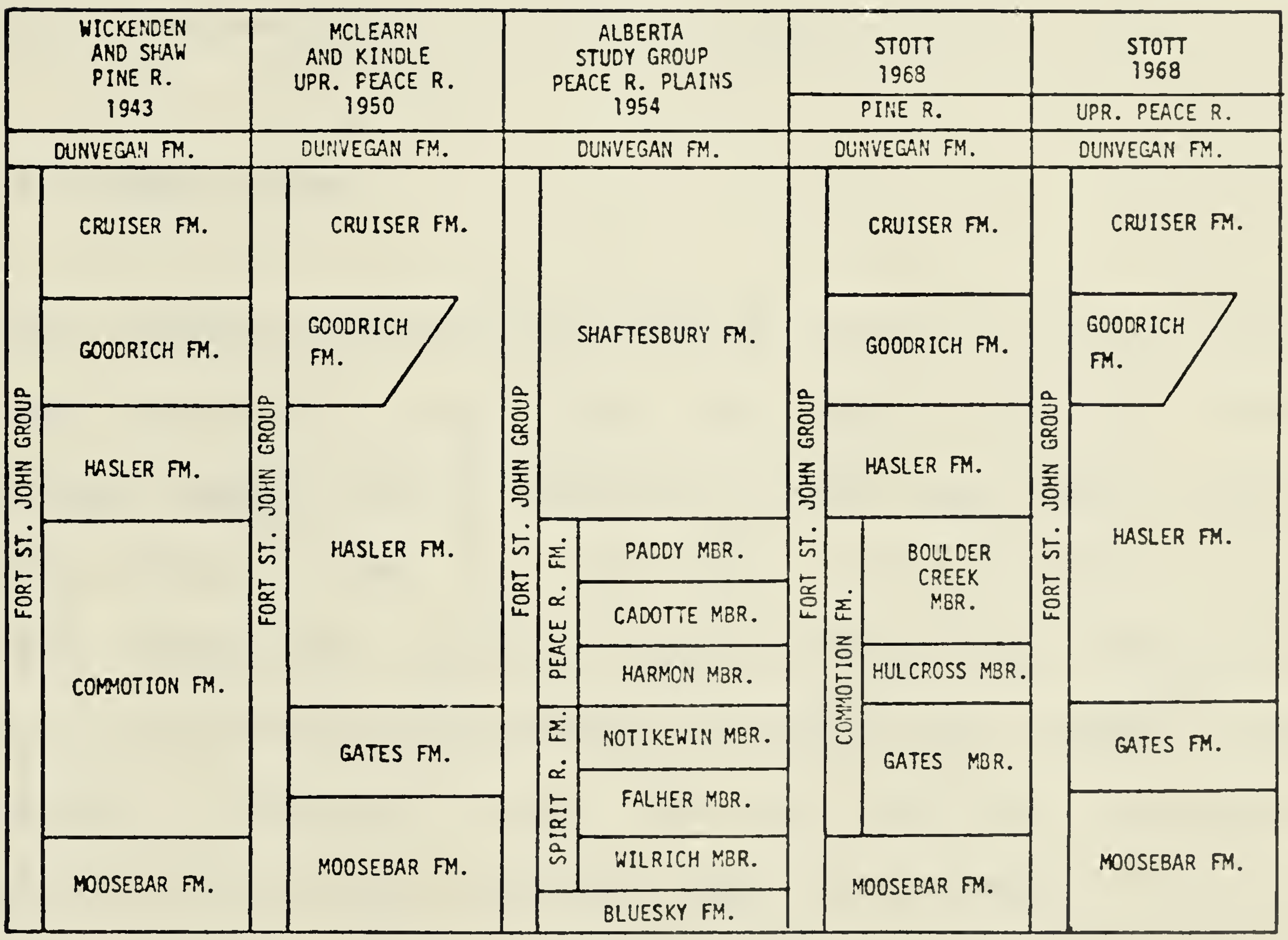

Figure 2 Development of the stratigraphy of the Fort St. John Group (after Stott, 1968).

sandstones with minor shale, coal, and conglomerate that overlies the Cadomin Formation is known as the Gething Formation (McLearn, 1923). The thickness of this formation was determined by Stott (1973) to be about 550m in the type area near the W.A.C. Bennett dam on the Peace River. Since it changes facies westward (and downward) into conglomerates of the Cadomin Formation, the distinction between these two formations is based on lithology only. The age of the Gething is Hauterivian to earliest Albian (Stott, 1973).

Fort St. John Group

The shales and interbedded sands noted by Selwyn along the upper Peace River were given the name Fort St. John Shales by Dawson (1881). Originally, the term applied only to rocks between what are now the Gates Sandstone and Dunvegan Formation. McLearn (1932) expanded the meaning of "Fort St. John Shale" to embrace all sediments between the underlying Bullhead Group and the overlying Dunvegan Formation. Stott (1968) followed this latter usage, which is now well accepted. Figure 3 gives a summary of lithologies in the Fort St. John Group.

Along the foothills belt from the Pine River the Fort St. John Group shows some lateral variation north towards the Peace River. This primarily reflects a decrease in the relative amount of sandy beds to the north. Along the Peace River downstream from Hudson Hope there is also a decrease

of sand members toward the Alberta border.

Moosebar Formation

This formation, the lowest of the Fort St. John Group, is a sequence of dark marine shale. Originally defined by McLearn (1923) from a 250m section near "Contact Point" in the central Peace River canyon, it has since been found to vary in thickness from 25m on the Kakwa River to about 300m near the type area (Stott, 1968). The base of the formation is commonly marked by a pebble bed resting on the underlying Gething Formation. It becomes silty near the top and shows a gradational contact with the overlying Gates Sandstone.

Commotion Formation

Wickenden and Shaw (1943) defined the Commotion Formation as a sequence of sandstone, shale, and conglomerate overlying the Moosebar Formation. In the region between the Smoky and Peace Rivers it is readily divided into 3 members: a basal Gates, middle Hulcross, and an upper Boulder Creek Member.

The Gates Member of the Commotion Formation is essentially equivalent to the Gates Formation of the Peace River Canyon. In this report, the Gates sediments will be called the Gates "Sandstone" for the sake of consistancy. McLearn (1923) named this massive sandstone after the

STAGE	GROUP	FORMATION		THICK-NESS (M)	LITHOLOGY
CENOMANIAN	FORT ST. JOHN	DUNVEGAN FM.		90-365	Marine and non-marine sandstone and shale
CENOMANIAN	FORT ST. JOHN	SHAFTESBURY FM.	CRUISER FM.	105-240	Dark grey marine shale with sideritic concretions; some sandstone
ALBIAN	FORT ST. JOHN	SHAFTESBURY FM.	GOODRICH FM.	15-410	Fine-grained cross-bedded sandstone; shale and mudstone
ALBIAN	FORT ST. JOHN	SHAFTESBURY FM.	HASLER FM.	150?-460	Silty, dark grey marine shale with sideritic concretions; siltstone and sandstone in lower part; minor conglomerate
ALBIAN	FORT ST. JOHN	COMMOTION FM.	BOULDER CREEK MBR.	90-170	Fine-grained, well sorted sandstone; massive conglomerate;non-marine sandstone and mudstone
ALBIAN	FORT ST. JOHN	COMMOTION FM.	HULCROSS MBR.	0-135	Dark grey marine shale with sideritic concretions
ALBIAN	FORT ST. JOHN	COMMOTION FM.	GATES SS.	70-275	Fine-grained marine and non-marine sandstones; conglomerate; coal; shale and mudstone
ALBIAN	FORT ST. JOHN	MOOSEBAR FM.		30-305	Dark grey marine shale with sideritic concretions; glauconitic sandstone and pebbles at base
APTIAN	BULLHEAD	GETHING FM.		20-305	Fine- to coarse-grained, brown, calcareous, carbonaceous sandstone; coal, carbonaceous shale, and conglomerate
? BARREMIAN	BULLHEAD	CADOMIN FM.		15-180	Massive conglomerate containing quartzite and chert pebbles

Figure 3 Lithologies and approximate thicknesses of the Bullhead and Fort St. John rocks (after Stott, 1968).

"Gates" on the Peace River 12km downstream from Hudson Hope. Since the disposition of the lower part of this formation is unknown at that locality, Stott (1968) has presented a section at Steamboat Island (upstream on Peace River) as an additional standard. The lower contact of the Gates Sandstone is gradational with the underlying Moosebar Shale. Stott (1968) believes the upper boundary to be at a constant time horizon throughout the Foothills. The upper contact probably represents only a brief hiatus, possibly due to rapid subsidence in the Alberta trough and simultaneous marine onlap. Sandy beds with minor conglomerate are predominant lithologies in both the Pine and upper Peace River areas. The Gates Sandstone thins northward, however, to 65m at Steamboat Island (Stott, 1968), and the equivalents of its basal beds are included in the argillaceous Moosebar Formation on the Peace River.

The Hulcross Member of the Commotion Formation represents a return to deeper marine conditions, and is composed of predominantly argillaceous beds. Stott (1963) named it the Hulcross Member to emphasize the change in depositional environment that it represents. The lower contact of the Hulcross Member is marked by a thin layer of chert pebbles, indicating rapid transgression at that time (Stott, 1968). The upper contact, however, is transitional with overlying sandstones of the Boulder Creek Member. The Hulcross Member is poorly developed south of the Wapiti River, but attains a maximum thickness of about 135m on

Dokie Ridge (Stott, 1968), a locality north of the Pine River at about lat. 55° 40'N., long. 122° 25'W.

The upper member of the Commotion Formation, named Boulder Creek by Spieker (1921), is composed chiefly of conglomeratic and carbonaceous sandstones with four recognizable units. These units are: (a) thinly bedded marine sandstone overlain unconformably by (b) a chert pebble conglomerate overlain by (c) a coaly and plant-bearing sequence and (d) a top unit of conglomeratic sandstone (fig. 7). The lower contact is gradational, and is taken as the first bed of massive sandstone. The upper contact, however, is an abrupt change to dark, iron-rich shales of the Hasler Formation. Stott (1968) mentions a thickness for this member of about 275m on Dokie Ridge. It thins dramatically northward from 170m (Pine River area) down to virtually nothing so that on the upper Peace River its silty equivalents are included in the shales of the Hasler Formation.

<u>Hasler Formation</u>

Wickenden and Shaw (1943) named the Hasler Formation after Hasler Creek, a tributary of the Pine River. Originally described as the shales overlying the Commotion Formation, the Hasler was later assigned a type section near Dokie Ridge by Stott (1968). It is a succession of predominantly marine shales with rare sandy, silty, and

conglomeratic bands, depending on locality.

In the Pine River valley, the Hasler Formation is composed of 335 to 365m of beds (McLearn and Kindle, 1950) bounded on the top by the Goodrich Formation and resting on the Commotion Formation. On the upper Peace River the thickness of the Hasler Formation is unknown; the underlying Boulder Creek Member of the Commotion Formation pinches out and its equivalents are included in the Hasler Formation. The basal unit of the Boulder Creek Member is represented by a sandy shale section on the Peace River both within the canyon above Hudson Hope and below Hudson Hope at the "Gates". Thus the basal Hasler Formation is diachronous and includes lower beds to the north. Here the Gates Sandstone (or basal Commotion Formation) is given formation status while the equivalents of the overlying Boulder Creek and Hulcross Members form the basal Hasler Formation.

Goodrich Formation

The Goodrich Formation was first described by Wickenden and Shaw (1943) for sandstone beds lying between the argillaceous Hasler and Cruiser Formations. Stott (1968) designated type and standard sections for these rocks near Bowlder Creek and at Dokie Ridge, respectively. The formation thins rapidly to the north and east where its lower equivalents are included in the Hasler Formation. The upper contact is, however, more abrupt, and probably

represents a nearly constant time horizon in northeastern British Columbia (Stott, 1968). Black shales of the Cruiser Formation rest directly on massive sandstone. Stott (1968) gives the thickness of the Goodrich Formation as about 400m at Dokie Ridge.

Cruiser Formation

The dark grey shale and sandstone overlying the Goodrich Formation was called the Cruiser Formation by Wickenden and Shaw (1943). Because of the destruction of the original type section, Stott (1968) designated as type a section near Young Creek on the Pine River. At this locality, the Cruiser Formation is at least 220m thick. The lower contact is abrupt, often marked by a pebble bed; the upper contact appears gradational, but may not always be conformable (pers. comm. Stelck, 1979).

Dunvegan Formation

Composed primarily of massive-bedded coarse-grained sandstone and conglomerate, this formation lies unconformably on the Cruiser Formation. It generally thickens north and westward from less than 100m near Peace River (town) to about 250m in the Peace River foothills. The Dunvegan Formation is remarkably persistant in northeastern British Columbia. It is the uppermost formation of Stott's (1975) middle Cretaceous sequence.

TECTONIC FACTORS AFFECTING SEDIMENTATION

Omineca Geanticline

In Albian time, the principal source of detritus in northeastern British Columbia was the western cordillera. The main ranges of the Rocky Mountains as we know them today had only incipient expansion at this time (Stott, 1975, p. 457). It is therefore probable that the main source was farther west than the modern Rocky Mountain Trench. The "Omineca Geanticline", a positive area just west of the Trench (fig. 4) undoubtedly contributed much of the Bullhead and Fort St. John sediments (Stott, 1968, 1973). This feature follows the general trend of the cordillera traversing the whole of British Columbia from the north (the Omineca Geanticline proper) to the south, where it is called the Nelson uplift. This belt of igneous and metamorphic rocks apparently developed in Paleozoic time, but has undergone episodic deformations since then. Several "pulses" of activity in the Lower Cretaceous appear to be responsible for much of the Bullhead and Fort St. John sediments.

It is appropriate at this time to discuss the "Columbian Orogeny". The term refers to the continuing deformation of the western cordillera from late Jurassic to Tertiary time (Wheeler, 1967). Orogenic activity in the western mountain belt was originally thought by most workers to be "quantized" in compact, separate episodes. The Nevadan and Laramide events are well known examples. The former is

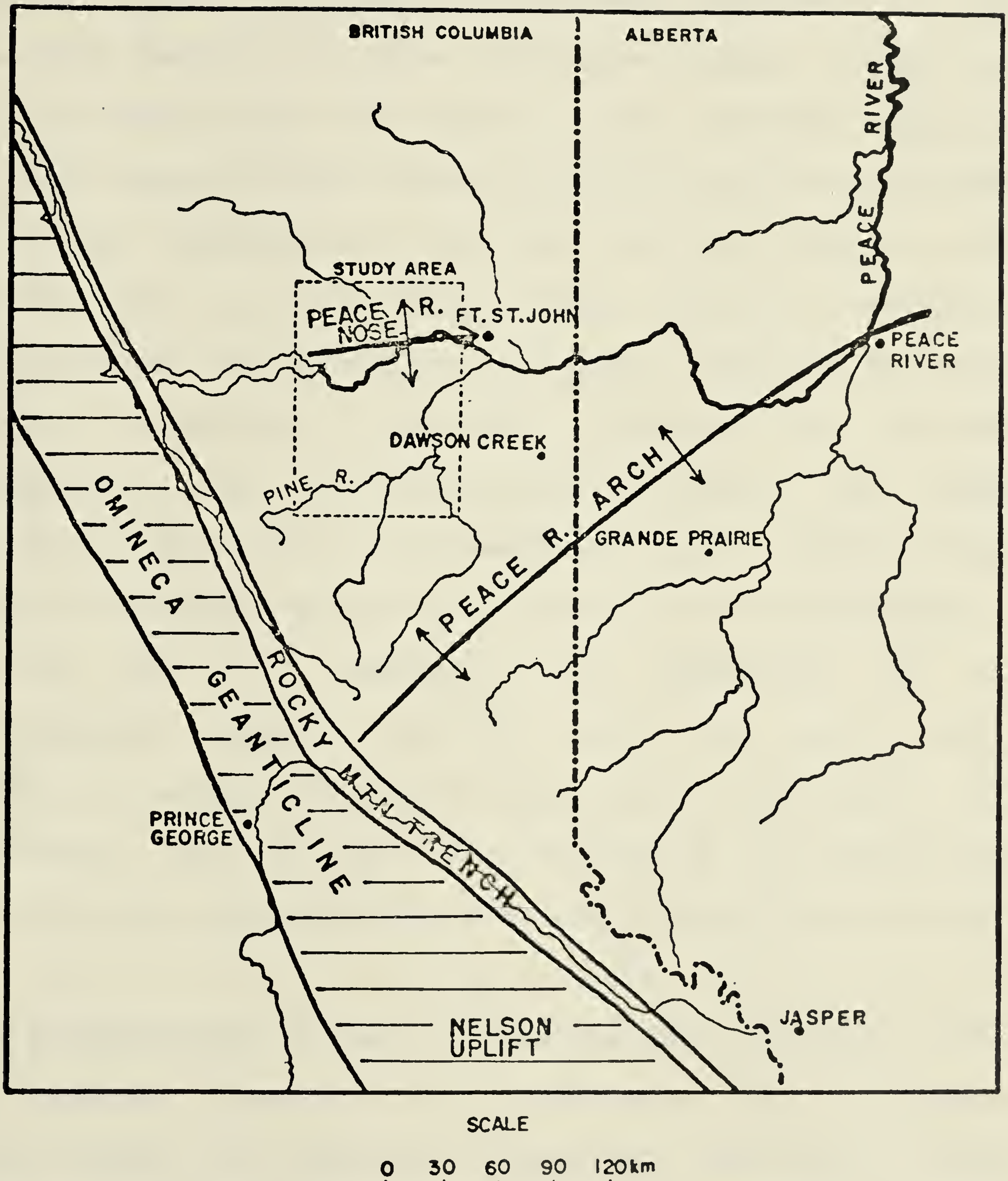

Figure 4 Some tectonic elements affecting Fort St. John deposition.

dated as late Jurassic, while the latter is thought to have occurred from latest Cretaceous to Eocene. It now appears that both events are the sum of many "pulses" of orogenic activity, often accompanied by increased deposition of the resulting detritus in the available basins. Price and Mountjoy (1970) imply that thrusting and folding began in the Main Ranges of the Rockies in latest Jurassic and early Cretaceous. Deformation in the Front Ranges, however, was delayed until late Cretaceous. Thus, a pattern develops in which faulting and deformation migrates eastward from the Omineca Geanticline (activity beginning in the late Jurassic) to the Foothills (active during the early Tertiary). This view is consistent with current plate tectonic theory in that orogenic pulses can be considered to coincide with the impinging or subduction of the northwesterly moving Pacific plate at the western continental margin. Periods of relatively slower uplift and quiescence may be some day correlated to strike-slip movement along such structures as the Rocky Mountain Trench.

Sedimentation in the Bullhead and Fort St. John Groups and Dunvegan Formation was synchronized with pulses of uplift along the Omineca Geanticline (Jeletzky, 1978). Periods of uplift and erosion in the geanticline should be acccmpanied by simultaneous deposition in the Alberta Trough (Stott, 1973). It follows that more pronounced uplifts would produce coarser sediments in the trough. Thus, the Cadomin Formation (conglomerate) forming the base of the Bullhead

Group would correspond to a major uplift in the Omineca Geanticline that occurred from Barremian to earliest Albian time (Stott, 1973). The overlying Gething beds fine upward to silt, mud, and ultimately coal, indicating that the source area was being levelled. Basin subsidence then became an important factor controlling deposition of the overlying Fort St. John Group. Increasing subsidence in the Alberta Trough allowed marine waters to inundate the basin in Albian time. The Fort St. John Group is thus dominated by finer sediments, the bulk of which are marine. A period of renewed tectonism in the Omineca Geanticline was responsible for the coarser sediments of the Dunvegan Formation. Stott (1975) considers this latter uplift to have occurred before the horizon of *Dunveganoceras*.

The Peace River Arch

In Paleozoic time, especially pronounced in the Devonian, a major northeasterly trending uplift appeared in northeastern British Columbia. It runs roughly through the towns of Peace River and Spirit River into British Columbia toward the headwaters of the Sukunka River (fig. 4). In the Paleozoic, this structure was a positive feature commonly referred to as the Peace River Arch. In the Mississippian, however, it apparently subsided and became depressed. Its actual structure is not known, but most workers agree that since the Paleozoic it carries the expression of basement faulting (e.g. Stott, 1968; Stelck, 1975).

Stott (1968, 1973, 1975) considered this structure to have been actively subsiding during much of Albian time. The greatest thickness of Bullhead and Fort St. John sediments lie just north of this structure (Stott, 1975). During the Albian marine invasion from the north, the structure may have acted as a "hinge" upon which the northern section of the Alberta Trough pivoted downward. Subsidence must have been suspended, however, during deposition of the Dunvegan Formation. In the Cenomanian, the rate of deposition had clearly overridden the rate of subsidence, resulting in non-marine deposits.

The Peace River Nose

The upper Peace River in the vicinity of Hudson Hope follows the axis of a major anticlinal structure mappable in the Fort St. John Group. The structure plunges gently to the east (fig. 4). This "Peace River Nose" might be considered a late Cretaceous or Tertiary structure except for two interesting facts: firstly, its axial trend is at a high angle to the cordilleran trend, and secondly, sands of the Boulder Creek Member pinch out on its southern flank. Recent studies by Stelck and Bredin (pers. comm. 1978) indicate that an additional sand wedge, at about the stratigraphic position of the Viking Formation of the Alberta plains, may also shale out on the south side of this feature. The evidence seems to imply that this structure was in existence

before the deposition of Fort St. John sediments, and was a contributing factor controlling their deposition. Increase in grain-size and in coal content is to the south, however, indicating a southern provenance for the sediments of the Boulder Creek Member (pers. comm. Stelck, 1979).

DEPOSITIONAL ENVIRONMENTS OF THE FORT ST. JOHN GROUP

A variety of both non-marine and marine environments of deposition existed in northeastern British Columbia during the Albian. The complex succession of conglomerates, sands, silts, and shales can be roughly grouped into 3 broad classifications: marine, transitional, and nonmarine (Stott, 1968). The non-marine category can be further subdivided into alluvial plain and piedmont alluvial plain environments. Transitional environments include deltaic and shoreline deposits.

Non-marine Environments

Tectonic activity in the western cordillera initiated the shedding of sediments into the Alberta Trough. When the rate of sedimentation was high, the result was a lowland plain gently sloping downwards from the mountains.

In northeastern British Columbia, extensive carbonaceous sediments (often including significant coal seams) are present in the Gates Sandstone and Boulder Creek

Member of the Commotion Formation south of the Pine River. This evidence, plus that of numerous plant fossils, suggests non-marine alluvial flood plain environments for these rocks. These units also contain finer laminated sediments as well as cross-bedded fluvial deposits. The laminated sediments are interpreted by Stott (1968) to be vertical accretion deposits formed on floodplains between the river channels and swamp lowlands.

Transitional Environments

Due to recurrent fluctutions in sea level, part of the Gates Sandstone and Boulder Creek Member in the Pine River area (south of Peace River) belong to the transitional environment. An additional transitional regime is recognized in the basal Moosebar when it interfingers with the underlying Gething. Also, the top of the Cruiser Shale is transitional with the Dunvegan Formation.

Marine Environments

The Goodrich Formation is considered by Stott (1968) to be primarily marine because of its rich marine fossil content. Marine fossils are also known from beds in the Gates Sandstone and Boulder Creek Member of the Commotion Formation (McLearn and Kindle, 1950).

The thick sequences of black shale in the Moosebar,

Hasler, and Cruiser Formations and Hulcross Member imply a restricted to open marine environment (Stott, 1968). The presence, in the shales, of pyrite, abundant organic material, glauconite, and siderite implies that reducing conditions existed beneath the sediment-water interface. The condition must have varied from open marine to somewhat brackish as ammonites (usually indicative of well oxygenated water of normal salinity) are found in some strata while only arenaceous foraminifera (often indicating restricted or brackish water) are found in others. Microfaunas examined by Stelck et al (1956) from the Harmon Shales (correlative with the lower Hasler Formation) were considered to represent an epicontinental sea with normal salinity and depth greater than 30m.

GENERAL ALBIAN PALEOGEOGRAPHY

In middle and late Albian time, the western interior region of Canada was flooded by an epicontinental sea (Stelck, 1958; Jeletzky, 1971). The Boreal connection(s) of this seaway were probably responsible for the appearance of the gastroplitid and neogastroplitid ammonite faunas that populated the Western Interior Basin at this time. The presence of Metengonoceras (Jeletzky, 1971, p.26) in the Neogastroplites Zone and Manuaniceras (Stelck, 1975) in the Paragastroplites liardense beds suggest that Gulfian connections must also have periodically occurred. The Middle and Upper Albian faunas of the western interior were thus

modified by both Boreal and Gulfian influences. These influences were, however, tempered by restrictions (both temporal and physical) to faunal migration which culminated in the development of the "Mowry Sea" (Warren and Stelck, 1959). Jeletzky (1971) pointed out that the "Mowry Sea" was not completely landlocked for all of the late Albian. It was, however, sufficiently restricted to permit the evolution of the endemic Neogastroplites faunas, and perhaps discourage the immigration of calcareous foraminifera.

DEPOSITIONAL HISTORIES

Bullhead Group

During deposition of the Cadomin-Gething rocks the whole of the study area was emergent. A major uplift to the west had flooded the basin with coarse sediments that fine eastward. Coal and argillaceous beds are also found, especially in the Gething Formation. Stott (1968, 1973) postulates two major river systems entering the lowland from the west: one had its locus near the headwaters of the Peace River while the other was well developed near the upper Murray and Wapiti Rivers. Both show concentrations of coarse Cadomin Conglomerate in these areas. Lower in the plain, between the Cadomin "fans" and to the east, swampy areas predominated. Ferns, conifers, and cycads formed coal swamps in these lowlands which were probably inhabited by dinosaurs, as their footprints are common in the Gething.

Moosebar Formation

Bullhead deposition ended with continuing subsidence allowing the Moosebar sea to invade northeastern British Columbia in the early Albian from the north. Stott (1968) considers the source of sediment to have been from the west. The Moosebar sea must have had relatively normal salinity, good circulation, and was probably not over 1000m deep. In support of this interpretation, it can be noted that a variety of marine organisms, including ammonites and both calcareous and agglutinated benthonic foraminifera flourished in this sea.

Gates Sandstone

During the deposition of the Gates Sandstone, the shoreline prograded into the Moosebar sea from the south. It roughly parallels the Peace River Arch, supporting Stott's (1968) theory that the Arch acted as a hinge upon which the northern part of the basin pivoted downward. The main sediment source appears to have been to the south of the study area. Paleocurrent direction was probably to the northeast (Stott, 1968), although no delta or river system flowing in that direction has yet been documented. Unconsolidated flow structures within the Gates Sandstone near Hudson Hope suggest a clinoform or upper slope environment here.

Hulcross Member

The Hulcross Member represents a return to marine conditions within the zone of Gastroplites. Apparently not as extensive as the older Moosebar sea, the Hulcross transgression was bounded to the south by alluvial deposits. In the lower Peace River area, Alberta, this transgression is recorded by the Harmon Member. In the northern part of the study area, marine conditions predominated during the deposition of the Moosebar, Gates, and Hulcross sediments. The equivalents of the Hulcross Member are found in the Buckinghorse Formation and perhaps in the shale separating the upper and lower Scatter Sandstones (see Stott, 1975). The transition of the Hulcross Member to the overlying Boulder Creek Member is abrupt and commonly contains conglomerate, perhaps indicating a rapid uplift in the source area to the south.

Boulder Creek Member

The arenaceous deposits of the Boulder Creek Member mark the regression of the Hulcross sea to what is now the Pine River. The shoreline was roughly parallel to the Peace River Arch, and the source of incoming detritus apears to have been from the south.

Hasler Formation

The Hasler Formation records a major transgression occurring from late *Gastroplites* to early *Neogastroplites* time. It seems also to mark a change in source area from the south to the west, for subsequent arenaceous deposits of the Goodrich Formation prograde into the basin along a front roughly parallel to the Rocky Mountains. The paleogeography of northeastern British Columbia was dominated by the "Hasler Embayment" during *Haplophragmoides gigas* time. This feature (fig. 5) was situated northwest of the Peace River Arch. The fact that *H. gigas* occurs on both sides of, but not over, the Peace River Arch suggests that the Arch was expressed as a peninsula at this time.

Goodrich Formation

The arenaceous beds of the Goodrich Formation represent marine environments. The Goodrich Formation and its northern equivalent, the Sikanni Formation, grade into shales included in the Shaftesbury Formation to the east. This indicates that tectonic activity in the cordillera produced a "flood" of coarse clastics in sufficient volume to cause sand bars on the western margin of the Mowry Sea.

Figure 5 North American paleogeography during deposition of the Hasler Formation (modified after Williams and Stelck, 1975).

Cruiser Formation

The Cruiser (or upper Shaftesbury) sea marks a cessation of excess sand delivery and an apparent still-stand as fish scale accumulations are known widely within this interval. To the east, marine conditions (recorded by the Shaftesbury Formation) had prevailed during the deposition of most of the Hasler Formation. The progradation and subsequent flooding of Goodrich-Sikanni deposits moved the strand line towards and away from the basin in a direction perpendicular to the trend of the Rocky Mountains. Since the strand margin itself was parallel to the cordilleran trend, it is likely that "Laramide" tectonics were affecting sedimentation. The final transgression of Lower Cretaceous time (marking the end of the "middle" sequence of Stott, 1975) is recorded in the Cruiser Formation and its equivalents in the Sully Formation farther north.

Dunvegan Formation

The marine Cruiser Formation gives way to widespread alluvial deposits of the Dunvegan Formation. The source of the latter sediments appears to be the Omineca Geanticline. Sufficient sediment was shed by this rising landmass that the basin was filled, and the continental environment prevailed throughout northeastern British Columbia. The open sea receded southeasterly to the Grande Prairie region and

the area east of Spirit River, Alberta.

CHAPTER THREE

BIOSTRATIGRAPHY

Introduction

Biostratigraphy has played a leading role in analyzing Cretaceous geochronology of the western Canadian Interior. Facies changes create diachronous lithostratigraphic units which, although useful in local correlation, cannot usually be relied on in regional or intercontinental work. Physical methods of age dating are notoriously difficult to apply to sediments. Radioactive techniques cannot stand by themselves unless corroborated by other (usually biostratigraphic) techniques (see Jeletzky, 1978).

In northeastern British Columbia, the vast thicknesses of shale and interbedded sands of the Lower Cretaceous can be dated using ammonites (fig. 6). They provide the basis for a zonal scheme drawn up by Jeletzky (1968). To a lesser degree, such pelecypods as *Inoceramus* and *Buchia* supplement the ammonite zonation. Microfossils (benthonic foraminifera in particular) have provided a coarser biostratigraphy for this region. The importance of the foraminiferal zonations (see Stelck et al. 1956; Caldwell et al., 1978) cannot be overestimated when resolving stratigraphic problems within thick shales with no preserved megafossils. Commonly, agglutinated benthonic Foraminifera and phytoplankton are the only fossils present. The use of foraminifera is mandatory within gaps in the ammonite zonations and is

commonly useful for the correlation of wildcat wells where only cuttings may be available for study.

THE CRETACEOUS SYSTEM

The Cretaceous System was defined by d'Halloy in 1813. In the classic British section, the Lower Cretaceous consists of the Lower Greensand and the Gault Clay. International correlation of this sequence to our western Canadian rocks is complicated by the scarcity of cosmopolitan ammonites, particularly common zonal forms. Poor preservation and extremely expanded sections also add to the problems of the mega-paleontologist.

The assignment of rocks to the Albian stage in western Canada depends heavily upon a single specimen of <u>Gastroplites</u> <u>cantianus</u> (Spath) found in 1937 in the Gault. This generic assignment has been questioned by Jeletzky (unpublished manuscript, 1979). The next universal forms common to both America and Europe are the acanthoceratid faunas of the Cenomanian. Thus, the absolute reference of North American forms to the Upper Albian of the classical European scheme is somewhat arbitrary.

CRETACEOUS MEGAFAUNAL ZONES IN WESTERN CANADA

Jeletzky (1968) introduced a zonal scheme for the Cretaceous of western Canada that is now widely accepted. Of primary importance to this thesis are the Albian and Cenomanian forms shown in figure 6. The following sequence was devised by Warren and Stelck in 1969. It represents an Albian-Lower Cenomanian zonal sequence for northeastern British Columbia.

Ammonites in descending order:

Beattonoceras beattonense
Irenicoceras bahani
Neogastroplites septimus
Neogastroplites maclearni
Neogastroplites americanus
Neogastroplites muelleri
Neogastroplites cornutus
Neogastroplites haasi
Paragastroplites liardense
Gastroplites cf. *cantianus*
Gastroplites canadensis

Although this zonation has far better temporal resolution than foraminiferal schemes, important gaps are present between the Albian horizons of *Gastroplites* and *Neogastroplites*. *Paragastroplites liardense* serves to fill only a small part of this gap; foraminiferal zonations must be relied on to identify this horizon in most cases. The *Haplophragmoides gigas* Zone and the younger *Miliammina manitobensis* fauna are found within this gap. The *Haplophragmoides gigas* assemblage is found above the zone of *Paragastroplites* where it provides an unusually distinct foraminiferal marker.

STAGES	SELECTED MOLLUSCAN INDICES	FORAMINIFERAL ZONES	SUBZONES
CENOMANIAN	*Dunveganoceras albertense* *Dunveganoceras cf. conditum*	*VERNEUILINOIDES PERPLEXUS*	*Gaudryina irenensis*
	Acanthoceras athabascense		*Ammobaculites gravenori*
	Beattonoceras beattonense	*TEXTULARIA ALCESENSIS*	
ALBIAN	*Neogastroplites mclearni*	*MILIAMMINA MANITOBENSIS*	*Haplophragmium swareni*
	Neogastroplites cornutus		*Haplophragmoides postis goodrichi*
	Neogastroplites haasi		*Verneuilina canadensis*
	Inoceramus comancheanus	*HAPLOPHRAGMOIDES GIGAS*	
	Paragastroplites liardense	*GAUDRYINA NANUSHUKENSIS*	*Ammobaculites wenonahae*
	Gastroplites cf. canticanus		*Ammobaculites sp.*
	Gastroplites canadensis *Gastroplites kingi*		*Haplophragmoides multiplum*
	Arcthoplites mcconnelli *Arcthoplites irenense*		*Marginulinopsis collinsi -- Verneuilinoides cumingensis*
			Trochammina mcmurrayensis
	Cleoniceras subbayleyi		*Rectobolivina sp.*

Figure 6 Albian Foraminiferal Zones and Subzones with selected index megafossils (after Caldwell et. al., 1978).

FORAMINIFERAL ZONATION

Foraminiferal zones are necessarily more vague than ammonite zones because of the simplicity and consequent "evolutonary flexibility" of foraminifera. Foraminifera with very simple shapes e. g. Bathysiphon, Hyperammina, Saccammina commonly have very long specific ranges due, at least in part, to extinctions and later reappearances of the "same" form. Similar morphotypes have doubtless evolved many times during geological history; parallel and recurrent evolutionary patterns are commonly seen. Zones based on foraminifera are mostly assemblage zones, as the appearance of a single species or morphotype is seldom conclusive proof of the age of its enclosing sediments. Generally, a single species may have a relatively long range, but its juxtaposition with other discrete forms is relatively short in duration.

Recently, Caldwell et al. (1978) published the first integrated foraminiferal zonation scheme for the western Canadian Cretaceous. The Albian zones of Miliammina manitobensis, Haplophragmoides gigas, and Gaudryina nanashukensis are directly pertinent to this thesis. The M. manitobensis and G. nanashukensis Zones are divided into subzones named after a characteristic species occurring in each. These zones (Caldwell et al., 1978) are diagrammed in figure 6, opposite selected ammonite zones.

GAUDRYINA NANASHUKENSIS ZONE

Six subzones comprise this zone (defined by Caldwell et al., 1978). They are named for the following species (ascending order): *Rectibolivina* sp., *Trochammina mcmurrayensis*, *Marginulinopsis collinsi*-*Verneuilinoides cummingensis*, *Haplophragmoides multiplum*, *Ammobaculites* sp., and *Ammobaculites wenonahae*. The upper 4 subzones are relevant to this thesis and will be reviewed in detail here. The 2 lower zones are roughly the age of the Bullhead Group and its equivalents.

Marginulinopsis collinsi-*Verneuilinoides cummingensis* Subzone

Principal elements:

Ammobaculites fragmentarius Cushman
Ammobaculites petilus Eicher
Discorbis norrisi Mellon and Wall
Gaudryina canadensis Cushman
Globulina lacrima Reuss var. *canadensis* Mellon and Wall
Gyroidina cf. *nitida* Reuss
Haplophragmoides gigas Cushman var. *minor* Nauss
Haplophragmoides linki Nauss
Haplophragmoides sluzari Mellon and Wall
Lenticulina bayrocki Mellon and Wall
Marginulinopsis collinsi Mellon and Wall
Miliammina manitobensis Wickenden
Miliammina sproulei Nauss
Miliammina subelliptica Mellon and Wall
Nodosaria aff. *proboscidea* Reuss
Patellina ellioti Stelck and Wall
Pseudonodosaria clearwaterensis Mellon and Wall
Quadrimorphina albertensis Mellon and Wall
Saccammina alexanderi (Loeblich and Tappan)
Saracenaria projectura Stelck and Wall
Saracenaria trollopei Mellon and Wall
Tritaxia athabaskensis Mellon and Wall
Verneuilinoides cummingensis (Nauss)

This zone is interesting because of its considerable calcareous content. It was originally named for a primarily calcareous fauna from Clearwater Formation in the Fort McMurray area of Alberta (Mellon and Wall, 1956). Later, it was realized that these forms represent one of two biofacies present occurring in the present subzone (Caldwell et al., 1978). The dominantly arenaceous V. cummingensis biofacies (probably equivalent to the Haplophragmoides gigas minor zone of Stelck et al., 1956) includes those forms representative of nearshore and brackish marine environments while the calcareous fauna is thought to indicate more open marine conditions.

The age of the present zone is early Middle or late Early Albian. It probably corresponds to the Arcthoplites irenense and A. mcconnelli Subzones of Jeletzky's (1968) Beudandiceras affine Zone. Correlations based on the M. collinsi-V. cummingensis Subzone can be established for the Cummings Member of the Mannville Formation in Alberta, all of the Spirit River Formation except for the lower Wilrich Member, part of the upper Loon River Formation, the Moosebar Formation in British Columbia, and the equivalents of the latter Formation in the Blairmore Group in central and southern Alberta.

Haplophragmoides multiplum Subzone

Principal elements:

Gaudryina nanashukensis Tappan
Haplophragmoides cf. _kirki_ Wickenden
Haplophragmoides multiplum Stelck and Wall
Haplophragmoides postis Stelck and Wall
Verneuilinoides sp. aff. _V. cummingensis_

The original authors of this zone present a more detailed discussion of the specific content in Stelck et al. (1956). This zone is coextensive with both the Harmon Member of Alberta and the Hulcross Member of the Commotion Formation in northeastern British Columbia, and, as yet, has not been recognized outside the stratigraphic realm of these rocks. In spite of a lack of diagnostic megafaunas, the age of the zone can be inferred by its stratigraphic position as (middle) Middle Albian. The zone of _Beudanticeras affine_ lies below, and _Gastroplites kingi_ occurs in the upper part of the Hulcross Member (Stott, 1968).

Ammobaculites sp. Subzone

Principal elements:

Haplophragmoides linki Nauss
Ammobaculites 4 spp. (see Stelck et al., 1956, p. 15)
Haplophragmoides 4 spp.
Eggerella sp.
Miliammina 2 spp.
Glomospira sp.
Nodosinella sp.
"Proteonina" sp.

Wickenden (1951) described an assemblage of

Foraminifera from the Cadotte Member of the Peace River Formation, northwestern Alberta. This fauna, termed the "Cadotte Microfaunal Zone" by Stelck et al. (1956), was included in the _Ammobaculites_ sp. subzone by Caldwell et al. (1978). The subzone encompasses both the Cadotte Member of the Peace River Formation in Alberta and the lowest unit of the Boulder Creek Member of the Commotion Formation in British Columbia. The age is late Middle Albian. Since this subzone is coeval with the lower part of the general _Gastroplites_ zone, its age is readily determined. Caldwell et al. (1978) suggest that the subzone is limited in areal extent by the presence of an unconformity at the top of the Cadotte Member. Beds containing this fauna would likely be removed farther to the south.

Ammobaculites wenonahae Subzone

Principal elements:

Ammobaculites cf. _fragmentarius_ Cushman
Ammobaculites wenonahae Tappan
Ammodiscus mangusi Tappan
Ammodiscus rotalarius Loeblich and Tappan
Haplophragmium sp.
Haplophragmoides spp.
Hyperammina sp.
Psamminopelta bowsheri Tappan
Reophax troyeri Tappan
Saccammina alexanderi (Loeblich and Tappan)
Thuramminoides sp.
Trochammina cf. _eilete_ Tappan
Trochammina umiatensis Tappan
Trochammina rainwateri Cushman and Applin
Verneuilinoides sp.

This subzone is known only locally from the lower Hasler Formation on the Peace River 7km upstream from its

confluence with the Halfway River. The age is earliest Late Albian (Caldwell et al., 1978) as Gastroplites cf. cantianus occurs at the base while the bulk of the subzone is in the Paragastroplites liardense beds. The geographic extent of this fauna is believed to be limited by a westward extension of the post-Cadotte unconformity mentioned previously.

HAPLOPHRAGMOIDES GIGAS ZONE

Principal elements:

Ammobaculites fragmentarius Cushman
Ammobaculoides whitneyi (Cushman and Alexander)
Ammodiscus anthosatus Guliov
Ammodiscus kiowensis Loeblich and Tappan
Ammomarginulina asperata Guliov
Gaudryina canadensis Cushman
Glomospira cf. watersi Loeblich
Haplophragmoides cf. collyra Nauss
Haplophragmoides cf. cushmani Loeblich and Tappan
Haplophragmoides gigas Cushman
Haplophragmoides linki Nauss
Miliammina manitobensis Wickenden
Miliammina cf. manitobensis Wickenden
Miliammina sproulei Nauss

This zone is unusually well defined due to the presence of H. gigas. This distinctive foraminifer was was first recognized as a useful biostratigraphic marker by Cushman (1927). Stelck et al. (1956) defined the H. gigas zone on the basis of an assemblage of forms from the Joli Fou Shale of Alberta. Guliov (1967) expanded this definition and divided the H. gigas beds in Saskatchewan into two subzones: a lower one characterized by large specimens of H. gigas and Ammomarginulina asperata and an upper one containing small specimens of H. gigas (the "Miliammina sproulei subzone").

North and Caldwell (1975a) call these Zones the IIa and IIb respectively. They do not consider the smaller forms of H. gigas to be conspecific with the older, larger types. Caldwell et al. (1978) equated their H. gigas Zone to Zone IIa of North and Caldwell.

The age of the H. gigas Zone is considered by Caldwell et al. (1978) to be early Upper Albian. It appears to be equivalent to the Inoceramus comancheanus Zone (Stelck, 1975). The H. gigas Zone is widespread geographically for a foraminiferal Zone. It can be discerned in the Joli Fou Formation of Alberta and Saskatchewan, in the Skull Creek Member of the Ashville Formation in Saskatchewan and Manitoba (Guliov, 1967, McNeil, 1977), the middle Hasler Formation of northeastern British Columbia (this report), just below the Shaftesbury Formation on Peace River in Alberta (Wickenden, 1951), and in the upper Thermopolis Shale of Wyoming (Eicher, 1960).

MILIAMMINA MANITOBENSIS ZONE

This zone is one of the most widespread Foraminiferal Zones in western Canada, spanning most of the Plains and extending perhaps to the Arctic Ocean. Unfortunately, M. manitobensis sensu stricto has a long stratigraphic range, and delimitation of this Zone and its subzones depends heavily on auxilliary species and assemblage parameters. Specimens of M. manitobensis occur as low in the section as

the _Marginulinopsis collinsi-Verneuilinoides cummingensis_ Subzone of the _Gaudryina nanashukensis_ Zone.

The age of the _M. manitobensis_ Zone is considered by Caldwell et al. (1978) to be middle Upper Albian to late Upper Albian. It extends from beds devoid of diagnostic megafaunas up perhaps as high as the _Neogastroplites muelleri_ Subzone of the _Neogastroplites_ Zone (see Jeletzky, 1968, Stelck, 1975).

The broad range of _M. manitobensis_ sensu stricto has necessitated dividing the Zone into 3 subzones: _Verneuilina canadensis_, _Haplophragmoides postis goodrichi_, and _Haplophragmium swareni_, from oldest to youngest (Caldwell et al., 1978). The upper 2 subzones are as yet known only from northeastern British Columbia, while the lower subzone is much more widespread. The reasons for this largely remain a mystery, but it is worth noting that a possible paraconformity in the bone beds of the Fish Scales Marker might account for the missing section. Caldwell et al. (1978) suggest that the Fish Scale Marker may indeed represent a period of non-deposition that removed the 2 upper subzones from the record.

Verneuilina canadensis Subzone

Principal elements:

Ammobaculites fragmentarius Cushman
Ammobaculites pacalis pattersoni Sutherland and Stelck
Ammomarginulina cf. *paterella* Eicher
Arenobulimina paynei Tappan
Bathysiphon brosgei Tappan
Gaudryina canadensis Cushman
Gaudryina irenensis Stelck and Wall
Gaudryina spiritensis Stelck and Wall
Gaudryina tailleuri (Tappan)
Glomospira tortuosa Eicher
Gravellina chamneyi Stelck
Haplophragmoides cf. *gilberti* Eicher
Haplophragmoides linki Nauss
Haplophragmoides multiplum Stelck and Wall
Haplophragmoides cf. *topagorukensis* Tappan
Miliammina awunensis Tappan
Miliammina cf. *ischnia* Tappan
Miliammina manitobensis Wickenden
Psamminopelta bowsheri Tappan
Reophax minuta Tappan
Reophax sikanniensis Stelck
Reophax tundraensis Chamney
Saccammina alexanderi (Loeblich and Tappan)
Textularia topagorukensis Tappan
Thuramminoides septagonalis Chamney
Trochammina alcanensis Stelck
Trochammina cf. *rainwateri* Cushman and Applin
Trochammina rutherfordi Stelck and Wall
Trochammina umiatensis Tappan
Uvigerinammina cf. *athabaskensis* (Mellon and Wall)
Uvigerinammina manitobensis (Wickenden)
Verneuilina canadensis Cushman
Verneuilinoides borealis Tappan
Verneuilinoides cf. *fisheri* Tappan
Verneuilinoides kansasensis (Loeblich and Tappan)

Of the 3 *M. manitobensis* subzones, the *Verneuilina canadensis* fauna is the most widespread, embracing much of the western Canadian Plains. Wickenden (1951) referred to this assemblage as the "*M. manitobensis* Zone" and the term has been in the literature ever since. Stelck (1975) provided a more precise definition of this fauna in his

description of a diverse agglutinated fauna from northeastern British Columbia (see faunal list above). Caldwell et al. (1978) chose this locality to be the stratotype of the _V. canadensis_ Subzone.

The age of the present subzone is late Upper Albian. The top of the subzone in northeastern British Columbia corresponds to the lower beds of the _Neogastroplites haasi_ (_selwyni_) Subzone of Jeletzky's (1968) scheme. The lower part of the present subzone is in beds devoid of molluscs that occur above the _Paragastroplites liardense_ Subzone. The _V. canadensis_ Subzone can be recognized in upper beds of the Ashville Formation (Saskatchewan and Manitoba), the lower Colorado Group (Saskatchewn and Alberta), the Sunkay Member of the Blackstone Formation (Alberta), the lower Shaftesbury Formation (Alberta), and the uppermost beds of the Hasler and Buckinghorse Formations and lower Sikanni Formation in northeastern British Columbia.

Haplophragmoides postis goodrichi Subzone

Principal elements:

Ammobaculites pacalis pattersoni Sutherland and Stelck
Ammodiscus planus Loeblich
Bathysiphon brosgei Tappan
Glomospira glomerosa Eicher
Haplophragmoides gilberti Eicher
Haplophragmoides globosa Lozo
Haplophragmoides hendersonense Stelck and Wall
Haplophragmoides postis goodrichi Sutherland and Stelck
Haplophragmoides cf. _topagorukensis_ Tappan
Miliammina inflata Eicher
Miliammina ischnia Tappan
Miliammina cf. _sproulei_ Nauss

Miliammina moberliensis Sutherland and Stelck
Psamminopelta bowsheri Tappan
Reophax recta (Beissel)
Saccammina alexanderi (Loeblich and Tappan)
Saccammina cf. *lathrami* Tappan
Textularia gravenori Stelck and Wall
Textularia rioensis Carsey
Trochammina rutherfordi mellariolum Eicher
Trochammina umiatensis Tappan
Trochammina wetteri Stelck and Wall
Trochammina wickendeni Loeblich
Trochamminoides apricarius Eicher
Uvigerinammina cf. *manitobensis* (Wickenden)
Verneuilina alameda Eicher
Verneuilinoides perplexus Loeblich
Verneuilinoides stotti Sutherland and Stelck

The fauna of this subzone was described by Sutherland and Stelck (1972) from northeastern British Columbia. It occurs in the upper Hasler, Goodrich, and Cruiser Formations of the Fort St. John Group near Moberly Lake. The age was determined as late Upper Albian from neogastroplitid ammonites occurring in the stratotype. It corresponds to the upper *Neogastroplites haasi* (*selwyni*) and lower *N. cornutus* Subzones of Jeletzky's (1968) sequence. The *Haplophragmoides postis goodrichi* fauna has been found only at the type locality.

Haplophragmium swareni Subzone

Principal Elements:

Ammobaculites fragmentarius Cushman
Ammobaculites pacalis pattersoni Sutherland and Stelck
Bathysiphon brosgei Tappan
Dorothia cf. *chandlerensis* Tappan
Haplophragmium engleri Stelck and Hedinger
Haplophragmium swareni Stelck and Hedinger
Haplophragmoides hendersonense Stelck and Wall
Hippocrepina barksdalei (Tappan)

<u>Miliammina</u> cf. <u>ischnia</u> Tappan
<u>Miliammina</u> <u>moberliensis</u> Sutherland and Stelck
<u>Psamminopelta</u> <u>bowsheri</u> Tappan
<u>Reophax</u> <u>minuta</u> Tappan
<u>Reophax</u> cf. <u>pepperensis</u> Loeblich
<u>Saccammina</u> <u>alexanderi</u> Loeblich and Tappan
<u>Saccammina</u> <u>lathrami</u> Tappan
<u>Textularia</u> cf. <u>gravenori</u> Stelck and Wall
<u>Textularia</u> cf. <u>topagorukensis</u> Tappan
<u>Trochammina</u> <u>rutherfordi</u> <u>mellariolum</u> Eicher
<u>Trochammina</u> <u>umiatensis</u> Tappan
<u>Trochamminoides</u> cf. <u>apricarius</u> Eicher
<u>Verneuilinoides</u> <u>perplexus</u> (Tappan)

The present subzone was defined from material collected in British Columbia by Stelck and Hedinger (1976) from the lower Sully Formation on the Sikanni Chief River. It is considered to be upper Albian in age. Although no molluscs have been recovered from the type section, the immediately underlying Sikanni Formation contains <u>Neogastroplites cornutus</u>. At another locality 225km farther north, this ammonite has been recovered from the basal Sully Formation itself. The upper boundary of the subzone is the Fish Scales marker horizon, considered to represent the boundary between the Lower and Upper Cretaceous. To date the present subzone has only been recognized in the type section, but it is postulated to occur in the lower Cruiser Formation in the Peace River area.

CORRELATION OF THE FORT ST. JOHN GROUP

Moosebar Formation

Important zonal fossils reported from the Moosebar Formation include *Arcthoplites* (*Freboldiceras*) *irenense* and the *Lemuroceras*-*Beudanticeras* group. These ammonites are dated at Early to Middle Albian. Microfaunas recovered from the Moosebar Formation include both agglutinated and calcareous benthonic foraminifera. It is the only known occurrence of Albian calcareous benthonic foraminifera in the study area. A large assemblage of foraminifera from this formation was listed by Stott (1968, p. 55-56). Of these, *Quadrimorphina albertensis* Stelck and Wall and *Marginulinopsis collinsi* Stelck and Wall are considered as valid index fossils by Chamney (in Stott, 1968). These forms permit correlation with the lower Moosebar of the Pine River area (Stelck et al., 1956) and the lower Clearwater Shale on Athabaska River. Mellon and Wall (1956) correlated the lower Moosebar Formation on Hasler Creek with the upper McMurray Formation, the basal Clearwater Formation, part of the Loon River Formation, the lower beds of the Falher Member of the Spirit River Formation, and the Cummings Member of the Mannville Formation, all sections in Alberta and British Columbia.

Gates Sandstone

This unit is the lower member of the Commotion Formation on the Pine River. Beudanticeras spp. have been reported from this sandstone by McLearn and Kindle (1950) and by Stelck et al. (1956). In addition, Stott (1968) reported an early gastroplitid ammonite from the base of the Gates Sandstone. This evidence establishes the age as being middle Albian.

A large flora was reported from the Gates Sandstone by Mellon et al. (1963) and by Stott (1968). Although generally agreed to be "Blairmore" type flora, there is some controversy as to whether it should be assigned to the Aptian or the Albian. Stott (1968) believes that the Blairmore may be "as young as middle Albian" on the basis of floral and radioactive dating techniques. Thus, the Gates Sandstone may be correlated with the upper Luscar and middle Blairmore Formations of central and southwestern Alberta.

Hulcross Member

The middle shale of the Commotion Formation was named the Hulcross Member by Stott (1968). Jeletzky identified some ammonites from this Member on the Peace River as Gastroplites cf. G. kingi, Gastroplites cf. G. allani, and Gastroplites n. sp. ex. aff. G. liardense (Whiteaves). These fossils are considered to be late Middle Albian in age.

Boulder Creek Member

This sandstone, the upper Member of the Commotion Formation, is considered by Stott (1968) to be late Middle Albian in age. Species of *Gastroplites* are found near the base of this unit (McLearn and Kindle, 1950, and Stott, 1968). These occurrences allow correlation with the lower Hasler Formation (Starfish Creek locality), the upper Scatter and lower Lepine Formations at Liard River (McLearn and Kindle, 1944), and the Cadotte Member of the Peace River Formation on lower Peace River (Stelck et al., 1956). Other information suggests correlation with part of the Buckinghorse Formation and the upper part of the Sans Sault Group in the Northwest Territories (Stelck et al., 1956). The dicotyledonous flora in the upper part of the Boulder Creek Member seems to be somewhat older than the upper Blairmore flora of the Crowsnest Pass area.

Hasler Formation

Correlations of this diachronous unit are difficult because of the scarcity of ammonites and other megafaunas. There is evidence that the *Gastroplites* fauna occurs in the lower Hasler Formation on Peace River (McLearn and Kindle, 1950, p. 80; Stott, 1968, p. 53). The latter reference also records *Inoceramus cadottensis* from shales exposed along the Peace River just below the "Gates" locality.

The first known occurrence of the Haplophragmoides gigas fauna in northeastern British Columbia is described in this thesis from beds in the Hasler Formation near the Hamlet of Attachie. The occurrence is stratigraphically well above the the horizons of Gastroplites mentioned in the previous paragraph. This fact supports the idea of Stelck (1958) that the Viking Formation is younger than the Cadotte Member of the Peace River Formation. The Cadotte Member contains Gastroplites (see Stott, 1968). On the Plains, the Viking Formation is underlain by the Joli Fou Formation, which also serves as the type section for the Haplophragmoides gigas zone (Stelck et al. 1956). It thus appears that the H. gigas zone is younger than Gastroplites, and that the Viking Formation cannot therefore be correlated with the Cadotte Member of the Peace River Formation. There has been a tendency in the literature to correlate the Cadotte Member with the Viking Formation (see Workman, 1959) because of their lithologic similarity. This problem has been termed the "Viking-Cadotte Controversy" by Stott (1968). Figure 10 illustrates an interpretation incorporating the results of this study.

The occurrence of the Haplophragmoides gigas zone in the middle Hasler Formation allows correlation of this unit with the Joli Fou Formation of the Alberta Plains, the Skull Creek Member of the Ashville Formation in Saskatchewan and Manitoba (Guliov, 1967, and McNeil, 1977), and the equivalent Skull Creek and Thermopolis Shales of the western

United States (Eicher, 1960).

Foraminiferids recovered from the Hasler Formation in this study include:

Bathysiphon brosgei Tappan, 1957
Bathysiphon vitta Nauss, 1947
Hippocrepina sp. A
Hippocrepina sp. cf. _H. barksdalei_ (Tappan), 1962
?_Hyperammina_ sp. alpha
Psammosphaera sp.
Saccammina alexanderi (Loeblich and Tappan), 1950
Saccammina lathrami Tappan, 1960
Thuramminoides sp. cf. _T. septagonalis_ Chamney, 1969
Ammodiscus kiowensis Loeblich and Tappan, 1950
?_Ammodiscus_ sp.
Glomospira sp. cf. _G. reata_ Eicher, 1960
Reophax sp. cf. _R. eckernex_ Vieaux, 1941
Miliammina sp. cf. _M. awunensis_ Tappan, 1957
Miliammina inflata Eicher, 1960
Miliamina ischnia Tappan, 1957
Miliammina manitobensis Wickenden, 1932
Psamminopelta bowsheri Tappan, 1957
Haplophragmoides collyra Nauss, 1947
Haplophragmoides gigas Cushman, 1927
Haplophragmoides sp. cf. _H. gilberti_ Eicher, 1965
Haplophragmoides sp. cf. _H. kirki_ Wickenden, 1932
Haplophragmoides linki Nauss, 1947
Haplophragmoides sp. cf. _H. postis_ Stelck and Wall, 1956
Haplophragmoides sp.
Trochamminoides sp. cf. _T. apricarius_ Eicher, 1965
Ammobaculites culmula Skolnick, 1958
Ammobaculites fragmentarius Cushman, 1927
Ammobaculites fragmentarius Cushman variety
Ammobaculites sp. cf. _A. humei_ Nauss, 1947
Ammobaculites tyrrelli Nauss, 1947
Ammobaculites sp. cf. _A. tyrrelli_ Nauss, 1947
Ammobaculites wenonahae Tappan, 1960
Ammomarginulina cragini Loeblich and Tappan, 1950
Haplophragmium sp. cf. _H. swareni_ Stelck and Hedinger, 1976
Haplophragmium sp.
Pseudobolivina variana (Eicher), 1960
Plectorecurvoides sp.
Trochammina depressa Lozo, 1944
Trochammina gatesensis Stelck and Wall, 1956
Trochammina sp. cf. _T. rainwateri_ Cushman and Applin, 1946
Trochammina rutherfordi Stelck and Wall, 1955
Trochammina rutherfordi s. sp. cf. _T. rutherfordi mellariolum_ Eicher, 1965
Trochammina wetteri Stelck and Wall, 1955
Trochammina sp. cf. _T. wickendeni_ Loeblich, 1946
Verneuilina canadensis Cushman, 1927
Gaudryina canadensis Cushman, 1943

Uvigerinammina manitobensis (Wickenden), 1932
Verneuilinoides cummingensis Nauss, 1947
Arenobulimina paynei Tappan, 1957
Gravellina chamneyi Stelck, 1975
Gravellina sp. cf. *G. chamneyi* Stelck, 1975
Gravellina sp.

Figure 7 shows the approximate relationships of the three sampled sections to the local stratigraphy of the Fort St. John Group and selected index fossils. It can be seen that the "Attachie" section falls within the *Haplophragmoides gigas* Zone and that the "Farrel" section is coeval with the *Ammobaculites wenonahae* Subzone. The "Hasler" section appears to have affinities with the *Verneuilina canadensis* Subzone, but occurs lower in the section and is much less diverse.

Some authors (e.g. North and Caldwell, 1975a) do not consider the small specimens of *H. gigas* (those specimens found in zone IIb of North and Caldwell, 1975a, and in the *M. sproulei* Subzone of Guliov, 1967) to be conspecific with the larger examples first described by Cushman (1927). Assuming that they are not conspecific, it is still apparent that the "Attachie" section represents an expanded version of the upper part of the classic *H. gigas* Zone (equals the *M. sproulei* Subzone of Guliov, 1967, zone IIb of North and Caldwell, 1975a, and the beds immediately above the *H. gigas* Zone of Caldwell et al., 1978).

It is the author's opinion, however, that both small

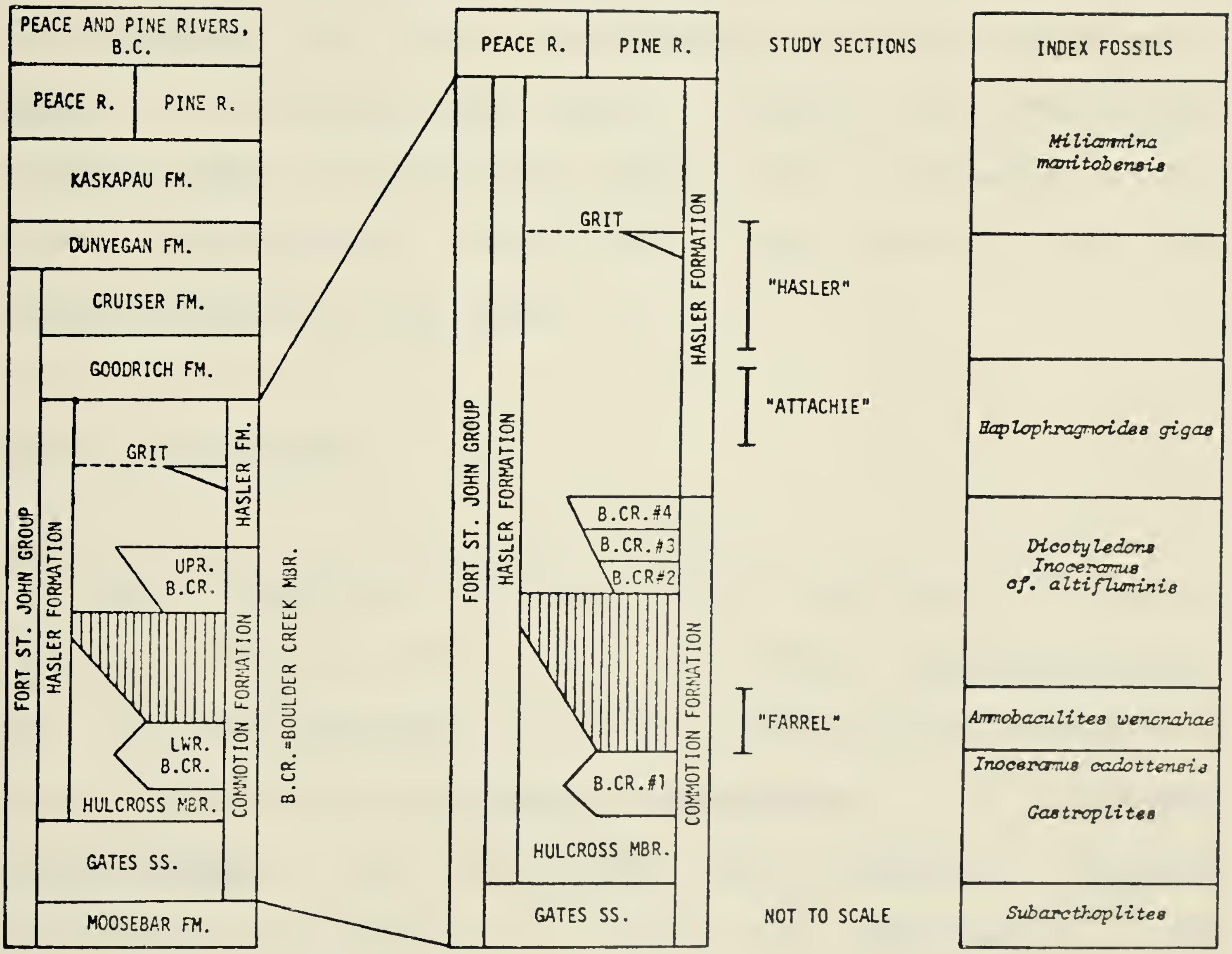

Figure 7 Relationship of study sections to local stratigraphy and index fossils.

and large specimens of _H. gigas_ are conspecific, and that the range of _H. gigas_ should not be restricted. McNeil (1977) reports that _H. gigas_ reaches a size maximum just above the base of the Skull Creek Member of the Ashville Formation. It decreases in size both towards the base and the top of the Member, which is considered by McNeil (ibid.) to be coeval with the _H. gigas_ Zone proper. Further, similar size changes in other foraminifers parallel those of _H. gigas_. It is thus probable that a change in environment (likely lower temperature caused by a deepening of the water) corresponds with the size maxima of the foraminiferids in this zone.

Goodrich Formation

This sandstone contains a fauna considered by Jeletzky (in Stott, 1968, p. 100) to be of general _Neogastroplites_ age. The most important elements of this fauna recovered by Stott (1968) include _Poisidonia moberliensis_ and _Posidonia goodrichensis_, both varieties of _Posidonia nahwisi_ considered by Jeletzky to occur in association with _Neogastroplites selwyni_ and _N. cornutus_.

On the basis of the preceding argument, the Goodrich Formation can be correlated with _Neogastroplites_-bearing beds in the Shaftesbury Formation in the Grande Cache area (Thorsteinsson, 1952), the Lone Mountain area (McLearn and Henderson, 1944), and on Peace River below Hudson Hope

(McLearn, 1944b). The Sikanni Formation on the Sikanni Chief River also contains Neogastroplites (McLearn, ibid.).

Cruiser Formation

Although no index fossils have been reported from the Cruiser Formation, its age can be inferred as latest Albian to late Early Cenomanian. The underlying Goodrich Formation contains the Neogastroplites fauna of Late Albian age, and the overlying Dunvegan Formation is Cenomanian. The Cruiser Formation has been correlated with the Sully Formation of northeastern British Columbia (Stott, 1968, p. 103). The lower Sully Formation in the Sikanni Chief River area was designated as the stratotype of the Haplophragmium swareni Subzone of the Upper Albian Miliammina manitobensis Zone (Caldwell et al., 1978).

CORRELATIVES OF THE HASLER FORMATION

The discovery of the Haplophragmoides gigas fauna in the Hasler Formation permits its correlation with a number of rock units in the western Canadian plains and in the United States. This section is included to show the faunal content and lithologies of these equivalent units. Figure 8 shows the inferred relationships of the units discussed.

The Joli Fou Formation

The Joli Fou Formation is a widespread black shale occurring in east-central Alberta and Saskatchewan. It is bounded above by the Viking (Pelican) Formation and below by the upper beds of the Blairmore Group (Grand Rapids Formation in northeastern Alberta and Saskatchewan). In Alberta, the Joli Fou Formation varies in thickness from about 15-40m and is about 35m thick on the Athabasca River (Alberta) at the type section for the *Haplophragmoides gigas* Zone (Bahan, 1951).

Bahan (1951) recovered an extensive suite of arenaceous microfauna from the Joli Fou Formation in north-central Alberta. His studies form the basis of the Stelck et al. (1956) definition of the *Haplophragmoides gigas* microfaunal zone in Alberta as coextensive with the type section of the Joli Fou Formation. *H. gigas* itself occurs only in the basal part of the zone (Bahan, 1951) over a distance of about 20m. Thus, part of this section correlates with the "Attachie" section (this study). These sections are separated by several hundred kilometers distance and are found on opposite sides of the Peace River Arch.

In Saskatchewan, the Joli Fou Formation underlies the Southern portion of the province and probably extends into southwestern Manitoba (Guliov, 1967). It does not outcrop in the province. As in Alberta, the Joli Fou Formation is

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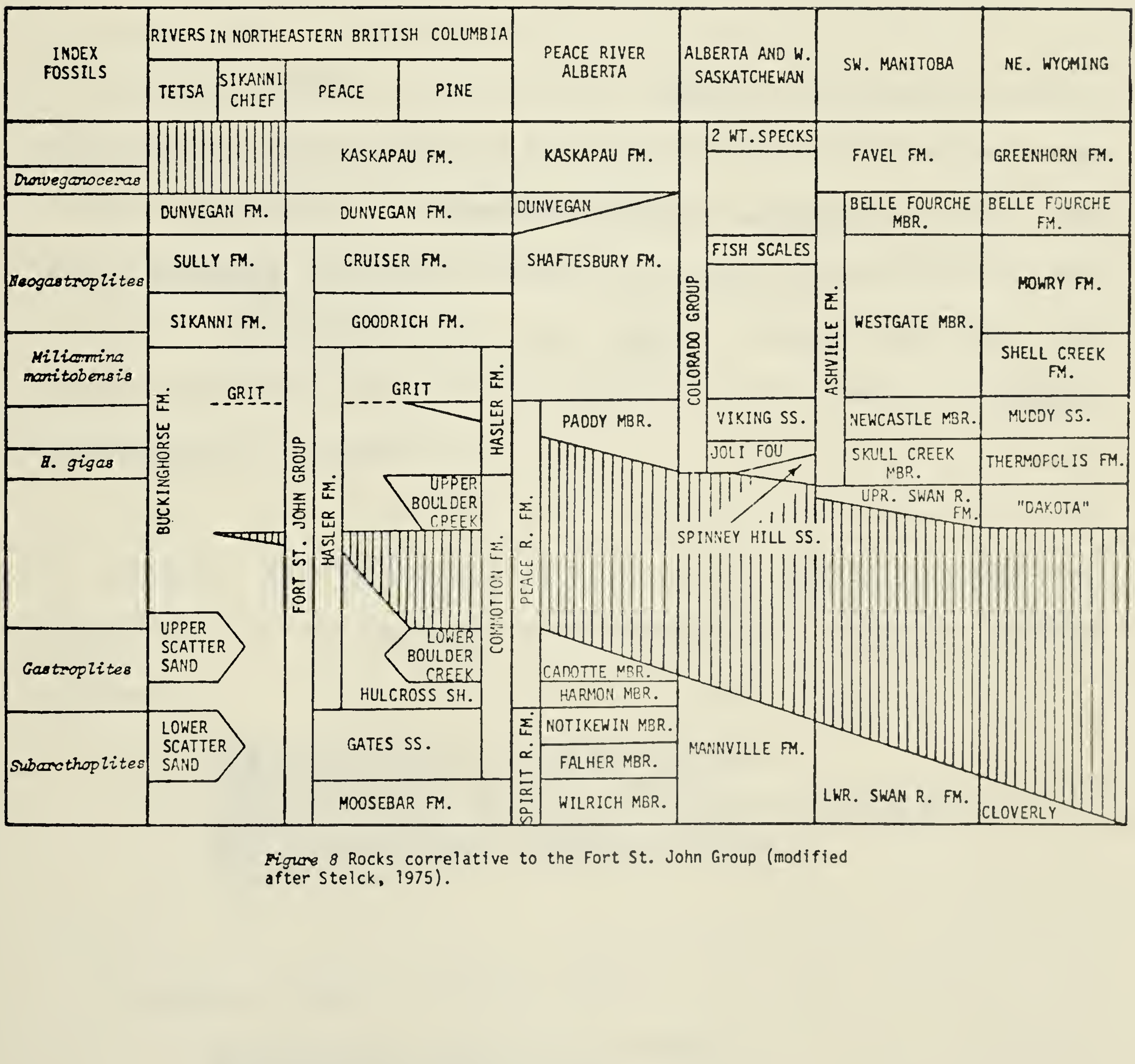

Figure 8 Rocks correlative to the Fort St. John Group (modified after Stelck, 1975).

overlain by the Viking Formation and underlain by the Mannville Group (Blairmore). The base of the Joli Fou Formation in west-central Saskatchewan south to Swift Current is characterized by sandy beds known as the Spinney Hill Member. This lithologic change probably represents the deltaic deposits of an Albian river with its source in the Precambrian rocks to the north (Edwards, 1960).

Guliov (1967) divides the H. gigas microfaunal zone in Saskatchewan (co-extensive with the Joli Fou Formation) into 2 faunal subzones: the Ammomarginulina asperata Subzone and the Miliammina sproulei Subzone. H. gigas characterizes both of these subzones, but the upper subzone contains only smaller specimens (probably indicative of more favorable environmental conditions).

Guliov (1967) found that the following species were restricted to his (lower) Ammomarginulina asperata Guliov Subzone:

Ammomarginulina asperata Guliov
Ammobaculites petilus Eicher
Ammobaculoides phaulus Loeblich and Tappan
Haplophragmoides uniorbis Eicher
Saccammina sp.

Common to both subzones are:

Haplophragmoides gigas Cushman
H. kirki Wickendon
H. linki Nauss
Gaudryina hectori Nauss
Ammobaculites fragmentarius Cushman variety
A. euides Loeblich and Tappan
A. tyrrelli Nauss
A. sp.

Ammobaculoides whitneyi (Cushman and Alexander)
_A._ sp.
Saccammina cf. _alexanderi_ (Loeblich and Tappan)
Ammodiscus anthosatus Guliov
_A._ sp.
A. kiowensis Loeblich and Tappan
Hippocrepina sp.
Uvigerinammina cf. _manitobensis_ (Wickenden)
Ammomarginulina sp.
Trochammina depressa Lozo
Bathysiphon cf. _vitta_ Nauss

The upper or _Miliammina sproulei_ Subzone contains the following forms in addition:

Reophax 3 spp. (see Guliov, 1967)
Miliammina sproulei Nauss
M. manitobensis Wickendon
M. inflata Eicher
M. ischnia Tappan
Psamminopelta sp.
Hedbergella sp.
Glomospira tortuosa Eicher
Flabellammina cf. _magna_ Alexander and Smith

It is this assemblage that correlates best with the "Attachie" section.

The Buckinghorse Formation

The Buckinghorse Formation was given its name in 1944 by C. Hage of the Geological Survey of Canada. This term is currently used to describe a thick (about 1000m) sequence of marine dark shales that outcrop in the foothills of northeastern British Columbia. Although the dominant lithology is shale, siltstones and sandstones are known from the middle of the Buckinghorse Formation, particularly to the north. In the vicinity of the Tuchodi and Tetsa Rivers

the formation can be resolved into upper and lower shale members and a middle sandy unit (Stott, 1967). These units are probably lateral equivalents to the (ascending) Garbutt, Scatter, and Lepine Formations of Kindle (1944).

The Buckinghorse Formation is overlain conformably by the Sikanni Formation (Hage, 1944). The Buckinghorse Formation is considered to be Albian on the basis of macrofossil collections. Gastroplitid faunas were discovered on Mason Creek 5km from its mouth on the Sikanni Chief River, 8km west of the Alcan Highway crossing. The *Gastroplites* fauna has been reported from the Buckinghorse Formation in the vicinity of Tetsa River (Henderson, 1954). There it occurs in the middle sandy member (Scatter Formation equivalents). This allows correlation of these sandy beds to the upper Scatter Formation, the lower part of the Boulder Creek Member of the Commotion Formation (Stott, 1968), and the Cadotte Member of the Peace River Formation. Thus, the upper Buckinghorse Formation is a very close equivalent to the type Hasler Formation.

Although many spot samples from the Buckinghorse Formation on Sikanni Chief and Buckinghorse Rivers were picked for foraminiferids, *Haplophragmoides gigas* did not occur. Many forms characteristic of the *Verneuilina canadensis* subzone were noted, and specimens suggestive of the "Attachie" suites were present. The spot samples were probably too high in section and inclusion of any of these

samples in the _H. gigas_ Zone impossible. About 300m of Buckinghorse section on the Sikanni Chief River remains unexplored, and it is the writer's contention that the _H. gigas_ Zone may be found in those rocks.

The Thermopolis Shale

Lupton (1916) named this black shale after the town of Thermopolis, Wyoming. Since he designated no specific type section, Eicher (1960) redefined the Thermopolis Formation (most often called the "Thermopolis Shale" by American geologists) to include shaly beds between the Cloverly Formation below and the Muddy Sandstone above. He further subdivided the Thermopolis Formation into the following units (from oldest to youngest): the rusty beds, the lower shale, the middle silty shale, and the upper shale. It is the microfauna of the "upper shale" that concerns this paper.

Eicher (1960) reports that arenaceous foraminiferids occur throughout the "upper shale". His faunal list (with modernizations added to the nomenclature) is as follows:

Ammobaculites euides Loeblich and Tappan
Ammobaculites fragmentarius Cushman
Ammobaculites obliquus Loeblich and Tappan
Ammobaculites petilus Eicher
Ammobaculites subcretaceous Cushman and Alexander
Ammobaculites tyrrelli Nauss
Ammobaculoides phaulus Loeblich and Tappan
Ammobaculoides whitneyi (Cushman and Alexander)
Ammodiscus kiowensis Loeblich and Tappan
Ammomarginulina cragini Loeblich and Tappan
Gaudryina canadensis Cushman
Glomospira reata Eicher

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Glomospira _tortuosa_ Eicher
Haplophragmoides _gigas_ Cushman
Haplophragmoides _linki_ Nauss
Lituotuba sp.
Miliammina _ischnia_ Tappan
Miliammina _inflata_ Eicher
Miliammina cf. _M_. _sproulei_ Nauss
Pseudobolivina _variana_ (Eicher)
Saccammina _alexanderi_ (Loeblich and Tappan)
Spirolocammina _subcircularis_ (Tappan)
Trochammina _depressa_ Lozo
Verneuilinoides _kansasensis_ Loeblich and Tappan

The similarities with type Joli Fou material are sufficient for a direct correlation. The common presence of such species as: _Ammobaculites_ _fragmentarius_, _Ammodiscus_ _kiowensis_, _Gaudryina_ _canadensis_, _Haplophragmoides_ _gigas_, _H_. _linki_, and _Miliammina_ cf. _M_. _sproulei_ certainly support this.

CHAPTER FOUR

FORAMINIFERAL ECOLOGY

Ecology of Living Foraminiferids

Studies on the ecology of Recent foraminiferids have become more available in the last decade because of an increasing interest in this field. This development is advantageous to micropaleontologists who have, in the past, had very little solid data to aid in the reconstruction of paleoecologies. The work of Murray (1973) and the proceedings of The First International Symposium on Benthonic Foraminifera of Continental Margins (Schaffer and Pelletier, eds., 1976) are particularly relevant to the study of living benthonic foraminiferids.

A rather large number of factors affect the diversity and abundance of living benthonic foraminiferids. Factors that should be considered are:

1. Salinity. Normal marine salinity is considered by Murray (1973) to be 32-37 parts per thousand. Obviously, salinity is controlled by 3 main factors: the evaporation rate, the rate at which fresh water is added to the system, and the possibility of equilibration with normal marine waters. Restricted and landlocked basins have little or no communication with open marine conditions; their salinity then depends on evaporation and/or addition of water. Some basins, for example the Baltic Sea (Murray 1973, p. 161),

show longitudinal salinity gradients and salinity depth stratifications.

Bradshaw (1957, 1961) found that Ammonia beccarii tepida (Cushman) survived at salinities ranging from 2 to 67 parts per thousand of normal sea salt. Optimum growth rate was achieved at salinities of 20 to 40 parts per thousand; a chamber was added to the test every 2 days. Reproduction occurred between salinities of 13 to 50 parts per thousand with the optimum salinity being 20 to 40 parts per thousand. Within this range reproduction occurred every 23 days. Specimens that reproduced near the extreme limits for reproduction usually had larger tests and more chambers than "normal" examples.

2. Temperature. This factor is roughly equivalent to latitude in its affect on foraminiferids. High latitudes (equivalent to low temperatures) tend to decrease the diversity of foraminiferid populations. Marine temperatures are, of course, affected by barriers to efficient thermal mixing and the configuration of ocean currents in any given area. Generally, however, temperature affects both the geographic range of a given species and its physiological processes.

Bradshaw (1961) conducted a series of experiments dealing with lethal and reproductive temperatures. A rotaliid, Ammonia beccarii tepida (Cushman) died at

temperatures of 45 to 46° C. Specimens allowed to acclimatize in 35° C seawater for 26 days died at 42-43° C. The same species had earlier been found by Bradshaw (1957) to remain alive at 10° C., but it was observed that no chambers were added. Also, the species was able to withstand a temperature of -2° C. for up to 2 hours. Reproduction in _A. beccarii tepida_ occurs between 20 and 32° C. with the optimum at 25 to 30° C. (ibid. 1961). It was apparent that the largest tests formed under the coolest conditions.

3. _pH_. Relative acidity of water is undoubtedly an important factor controlling foraminiferal assemblages. Normal seawater (pH 7.8) is locally altered in restricted or euxinic basins and unusual bottom conditions. Black muds are often acidic due to the evolution of hydrogen sulphide in anaerobic environments.

It was shown by Bradshaw (1961) that _Ammonia beccarii tepida_ (Cushman) could survive for 25 to 75 minutes under a pH of 2.0. He also noted, however, that the calcareous test was dissolved at sublethal acidic values without harming the animal. Upon return to normal marine conditions, a new test was secreted. It is interesting to speculate that calcareous benthonic foraminiferids might live under acidic bottom conditions without their tests.

4. _Depth_. It has been known for many years that foraminiferids are apparently depth controlled. However, the

nature of the relationship between assemblages and depth is far from clear. For example, Textularia schenki Cushman and Valentine occurs down to 180m in Todos Santos Bay (offshore Ensenada, Mexico), from 10 to 75m in the Gulf of California, and from 55 to 90m off San Diego, California. Other examples (Murray, 1973, table 21) show much greater discrepancies and deal with forms occurring as deep as 1500m. Clearly, factors other than depth are involved. Depth is closely related to such parameters as: pressure, light penetration, oxygen and carbon dioxide content, temperature and pH. Thus it is impossible to state anything but general relationships between foraminiferal assemblages and depth alone.

5. Substrate Types. Living benthonic foraminiferida live either in unconsolidated sediments (near the water/sediment interface) or on solid rocks, plants, or algae. Of those that live in sediments, both the infaunal and epifaunal life modes are represented. Such foraminifera are clearly affected by turbidity, turbulence, rate of sediment deposition and the chemical nature of the sediments.

Since foraminiferids are not capable of life in anaerobic conditions, oxygen penetration of the sediment is an important consideration. Indeed, a few deep basins such as those of the Baltic Sea may not support foraminiferids at all (Lutze, 1965). In normal marine muds an oxidized surface layer extends for some distance below the sediment/water interface. At some depth below this, reducing conditions are

encountered within which foraminiferids cannot live. Sandy sediments harbor foraminiferids to a greater depth than muddy deposits (Boltovskoy, 1966). He concluded that this relationship was due to the better circulation and hence improved oxygenation one would expect in coarser sediments. The same worker found rare living foramiiferids at depths of up to 16 cm.

Most benthonic foraminiferids extend pseusopodia into the sediment (infaunal) or upon the sediment surface (epifaunal) in order to feed. Clearly, in an area of active deposition the animals must constantly move up through the sediment to avoid being buried too deeply. Myers (1943) concluded that up to 80% of the individuals of *Elphidium crispum* (Linne) living in Plymouth Sound, England, in the subtidal zone are killed by burial in sediment mobilized by wave and current action. Thus, an area of extremely high sedimentation rate and poor oxygenation might support few or no benthonic foraminiferids. Also, dead assemblages composed primarily of *killed* individuals may show significant differences from normal populations in which most individuals evacuate their tests as a consequence of reproduction.

Foraminiferids living in the wave zone must resort to special techniques in order to survive. The majority of species find shelter in crevices and seaweeds, but some types may cement themselves to solid substrates or even

simply cling to the sediment with their pseudopodia.

6. Food Availability. This factor is important to paleontology because of the relationships between growth rate and test morphology. Bradshaw (1961) fed populations of *Ammonia beccarii tepida* (Cushman) varying quantities of food ranging from nothing to concentrations 4 times that required for a minimum growth rate. He found that starved specimens did not add new chambers and a gradual wasting of protoplasm volume was noted. Also, the latest formed chambers became empty. As food concentrations were increased, however, growth rates also increased and reproduction occurred more frequently. Maximum feedings (4 times the food required for a baseline growth rate) were probably not large enough to show any effects of "overnutrition".

Generally speaking, foraminiferids living in the photic zone require a mixed diet of bacteria and algae for optimum growth and reproduction, and most forms are selective in what they ingest. Very little is known about food requirements and feeding habits of deeper water foraminiferids.

7. Miscellaneous Factors. Schnitker (1967) cultured specimens of *Triloculina linneiana* d'Orbigny from a parent stock originating in Largo Sound, Florida. The parents were 0.65 to 1.0mm long with ribs and 11 chambers. The offspring, however, reproduced at the 4 to 5 chambered stage when the

test was only 0.125mm long. The empty tests after reproduction were spiroloculine or quinqueloculine; the parents were triloculine. This study provides an example of a foraminiferid reaching the reproductive stage before all usual test characters found expression. The conclusion was that favorable environmental conditions (in culture) enabled reproduction (and hence test evacuation) at an earlier growth stage. Myers (1943) found that populations of *Elphidium crispum* living in the subtidal zone of Plymouth Sound, England, were 60% larger and had 40% more chambers than populations of the same species living in the intertidal zone. Thus, one might expect larger forms in subtidal facies where wave action is reduced.

The preceding discussion has been presented in this paper to help explain some morphological variations observed in the present study. It is now clear that many species show normal variations in test morphology reflecting differences in the local environment. Other morphological variation arises through deformity, or as a consequence of the megalospheric and microspheric forms resulting from the normal foraminiferal life cycle. Such variations are understandably confusing to the paleontologist who deals entirely with fossil assemblages. There is little doubt that many fossil foraminiferal "species" are simply morphotypes of other, genetically identical, "species".

Environment of _Haplophragmoides gigas_

One of the most perplexing problems encountered during this study involves the size of _Haplophragmoides gigas_. The name itself implies a large form, but only small specimens were encountered in this study (up to 0.8mm). Cushman's original (1927) description notes sizes up to 2.25mm The average size of the "Attachie" specimens is smaller, and they often contain fewer than 10 chambers in the ultimate whorl.

The preceding discussion on modern foraminiferal ecology leads the writer to suggest that the small forms of _H. gigas_ from Attachie (and, indeed, the smaller forms described from the upper Joli Fou Formation and its equivalents by Guliov, 1967, and McNeil, 1977) lived under more ideal conditions than the larger typical forms. It has been shown that specimens of _Ammonia beccari tepida_ that reproduce near the upper or lower limits of tolerable salinity tend to have larger tests with more chambers. Cooler temperatures and low energy environments also tend to encourage larger size. Could analogous borderline conditions favour large, many-chambered specimens of _H. gigas_? It is the writer's opinion that both the small and large specimens of _H. gigas_ are conspecific, and the largest specimens lived under stress conditions, probably quiet cool water with subnormal salinity. A deepening of the water may have initiated any or all of these changes.

TEXTULARIINID ENVIRONMENTS

The species of foraminifera studied in this paper belong exclusively to the Textulariina. Although very little specific ecological data are available on these forms, Murray (1973, p. 248-251) outlined some general environmental parameters based on modern forms. The following information was selected from Murray's work for its applicability to arenaceous forms:

Ammobaculites
Hyposaline (<33 parts per thousand), sediment dwelling, temperate (?) to tropical waters, hyposaline marshes, lagoons, inner shelf.

Ammotium
Hyposaline to hypersaline (<33 parts per thousand to >37 ppt), sediment dweller, water temperature 0-30° C. depth intertidal to 10m, tidal marshes and hyposaline lagoons, estuaries and enclosed shelf areas.

Cribrostomoides
Hyposaline (30 ppt), to normal saline (33-37ppt), sandy sediment substrate, temperature <15° C. (?), depth 0-150m, shelf environment.

Cyclammina
Normal marine, sediment substrate, temperature about 10° C., depth >100m, outer shelf and bathyal environment.

Eggerella
Salinity 20-37 ppt., sediment dwelling, arctic to temperate climate, depth 0-100m, inner shelf, enclosed hyposaline shelf seas and lagoons.

Gaudryina
Normal marine, sandy sediment dweller, temperate climate zone, depth 50-460m, shelf seas and upper bathyal realm.

Jadammina
Salinity 0-50 ppt., sediment dweller, 0-30° C., intertidal environments and tidal marshes.

Miliammina
Salinity 0-50 ppt., sediment dweller, temperature range 0-30° C., depth 0-10m, hyposaline lagoons, hyposaline to hypersaline tidal marshes.

Reophax
Normal marine salinity, sediment dweller, Arctic to tropical waters, depth 0-150m, shelf environment.

Saccammina
Salinity 32-36 ppt., sandy sediment dweller, temperature <15° C., depth 0-100m, inner shelf environment.

Siphotextularia
Normal marine salinity, muddy sediment substrate, <10° C. (?), ?depth 150->1000m, deep outer shelf and bathyal.

Textularia
Normal marine salinity, sandy sediment substrates, Arctic to tropical waters, depth 50-640m, shelf and upper bathyal environment.

Trochammina
Group 1: Hyposaline to hypersaline waters, muddy sediment substrate, temperature 0-30° C., intertidal environment and tidal marshes.
Group 2: Normal marine salinity, sediment dweller, cold to temperate waters, depth 0-2000m, shelf and bathyal environments.

The preceding environments have to be used with caution when applied to ancient assemblages. It first must be determined (if possible) whether the specimens to be studied represent a life assemblage (bioccenose) or a death assemblage (thanatocoenose). If the latter is indicated, transport of tests or other post-mortem changes may render any conclusions completely unreliable. Another important concern involves the geological concept of uniformitarianism. Does a modern *Miliammina* live the same life style as an ancient one did? The writer intuitively believes that this sort of uniformitarianism can be applied

in most cases. However, anyone familiar with problems of foraminiferal taxonomy would concede that parallel evolution occurs in this group. The possibility of similar morphotypes evolving from genetically unrelated ancestors is also significant. If these processes had occurred, it would be unsafe to assume that the forms involved would occupy identical environments.

Environments of Studied Assemblages

This section deals with an attempt to assign an appropriate environment to each of the "Farrel", "Attachie", and "Hasler" sections. Only species with 100 or more individuals per section are used. This has been done to prevent small numbers of exotic or transported species from affecting the overall environmental interpretation. (Transport of tiny tests into deeper water by wave action is likely possible). Murray's (1973) environmental parameters are used. It should be reiterated that uniformitarian concepts are heavily relied on.

Farrel: Species with over 100 specimens

Thuramminoides cf. *septagonalis* Chamney
Psamminopelta bowsheri Tappan
Haplophragmoides cf. *gilberti* Eicher
Haplophragmoides sp.
Ammobaculites fragmentarius Cushman
Ammobaculites cf. *humei* Nauss
Ammobaculites tyrrelli Nauss
Ammobaculites wenonahae Tappan
Trochammina rutherfordi Stelck and Wall

Interpretation: This assemblage is primarily composed of species of Ammobaculites, Haplophragmoides, Psamminopelta, and Trochammina. An analogous assemblage based on Murray's (1973) environmental indicators might be composed of Ammobaculites, Cribrostomoides, Miliammina, and Trochammina (group 1). A synthesis based on Murray's data indicates that the "Farrel" section came from hyposaline waters, likely representing the inner shelf, lagoon, or tidal marsh environments. Temperature was probably 15° C. or less, and the substrate was fine-grained, often turbid sediment. Thus, it is possible that the "Farrel" sediments were deposited in a relatively shallow, temperate, hyposaline basin of depth not exceeding 150m (likely averaging 10-50m deep).

Attachie: Species with over 100 specimens

Psammosphaera sp.
Saccammina alexanderi (Loeblich and Tappan)
Reophax cf. eckernex Vieaux
Miliammina ischnia Tappan
Miliammina manitobensis Wickenden
Haplophragmoides gigas Cushman
Haplophragmoides cf. postis Stelck and Wall
Ammobaculites fragmentarius Cushman variety
Haplophragmium cf. H. swareni Hedinger and Stelck
Trochammina rutherfordi Stelck and Wall
Gaudryina canadensis Cushman
Gravellina cf. chamneyi Stelck
Gravellina sp.

Interpretation: The genera represented in the previous list can be compared to the following assemblage from Murray (1973): Ammobaculites, Ammotium, Cribrostomoides, Eggerella, Gaudryina, Miliammina, Reophax, Saccammina, and Trochammina (Group 1). Again, a hyposaline environment is implied,

although there were likely frequent reversions to near-normal salinity. The presence of _Gaudryine_, _Reophax_, and the _Eggerella_-like _Gravellina_ imply deeper water than the "Farrel" samples. The sea was probably often deeper than 100m, and likely exceeded 150m for significant periods of time. The climate was probably cool and temperate in "Attachie" time. This section displays an assemblage one could expect from slightly deeper and saltier waters than those implied by the "Farrel" samples.

Hasler: Species with over 100 specimens

Hyperammina sp. A
Miliammina _inflata_ Eicher
Miliammina _manitobensis_ Wickenden
Haplophragmoides _linki_ Nauss
Haplophragmoides cf. _postis_ Stelck and Wall
Ammobaculites _fragmentarius_ Cushman variety
Ammobaculites cf. _tyrrelli_ Nauss

Interpretation: This assemblage can be compared to the same environmental-indicating species (Murray, 1973) used for interpreting the "Farrel" environment. Again, a very shallow hyposaline basin is indicated. Climate was cool temperate, and depth was usually 5-25m with deeper periods not exceeding 150m.

Conclusion: All 3 sections studied contain only arenaceous foraminiferids. Of the 3, the "Farrel" is the least diverse. The "Hasler" section is next in increasing order of diversity, and the "Attachie" has the most forms. The "Hasler" and "Farrel" sections appear to represent a more

restricted, shallower, and less saline environment than the "Attachie". The extremely depauperate "Farrel" suite may reflect a more poisonous bottom condition than the similar, but more diverse "Hasler" forms.

The general environment of all 3 sections can be summarized as a cool temperate, shallow (5-150m.), restricted basin with reducing conditions not far below the sediment-water interface. The "Farrel" and "Hasler" assemblages reflect shallowings of the sea while the "Attachie" section probably represents a return to more normal marine conditions (deeper and more saline).

Note on Post-mortem Changes:

All samples examined in this study are either decalcified assemblages, or they never contained calcareous Foraminifera at all. If it is assumed that the former condition was indeed the case, post mortem changes involving the solution of tests must have occurred. Bradshaw (1968) and Murray (1973) reported that although calcareous forms are usually present (while living) in tidal marshes and other restricted waters, they are not always present in sediments within the same body of water. Bradshaw (1968) estimated that one day at pH. 5 would probably be sufficient to destroy unoccupied calcareous tests. Marshes are often at or below this value for at least part of the day.

In the studied assemblages, the presence of species of *Miliammina* and genera of the Textulariidae and Ataxophragmiidae indicate deeper water than typical salt marshes. It is very possible, however, that the samples represent decalcified shelf and or lagoon assemblages. The required acidity could have resulted from geologically "momentary" excursions to shallow, marshy water or from hydrogen sulphide generated in the sediment as a result of euxinic conditions. No pyritized steinkerns of calcareous foraminifers have been recovered, however.

MODERN ANALOGUES TO THE HASLER SEA

In the time of Hasler deposition, northeastern British Columbia was inundated by waters that must have been shallow, hyposaline, and relatively cool. The best modern examples of such an environment probably include Hudson's Bay and the Baltic Sea. On a smaller scale, similar environments are also found in modern lagoons, estuaries, and some deltas.

In modern assemblages, miliolid forms are absent or rare in environments (such as those in the preceding paragraph) where salinities are sub-normal. Murray (1968) showed that *Quinqueloculina semilunum* (Linne) lost control of its pseudopodial activity in hyposaline water (30 parts per thousand or less). He concluded that this was the reason that miliolids only colonize hyposaline environments in

places where normal salinities prevail for at least part of each day (e.g. estuaries). He goes further to postulate that this mechanism accounts for the usual absence of miliolids from hyposaline environments (Murray, 1973).

The absence of both rotaliids and miliolids from the assemblages studied in this paper indicate that other factors besides salinity controlled foraminiferal populations. Lutze (1965) believed that solution of calcareous tests was occurring in the Arkona Basin of the Baltic Sea. The same author noted etching of calcareous tests (some still containing protoplasm) of foraminifera from the Bornholm Basin, also in the Baltic. Thus some combination of low salinity with cool temperatures, high pressures, and abnormal bottom conditions may create dead assemblages composed exclusively of Textulariina. Another factor contributing to the apparent lack of calcareous forms in the Hasler Formation may involve dispersal mechamisms. Foraminiferal dispersal still remains a mystery, and students of the subject are unable to explain why "blooms" of a particular species occur in a given place at a specific time. Arenaceous foraminiferids may have possessed some reproductive advantage that allowed colonization of the shallow, restricted Hasler Sea while contemporary calcareous forms couldn't make it.

STATISTICAL CONCEPTS COMMONLY APPLIED TO FORAMINIFERIDS

Measuring Abundance

The abundance of foraminiferids in a sample can be expressed in two general ways: absolute abundance and relative abundance. Absolute abundance can be defined as the total number of foraminiferids recovered, either per sample, per slide (of picked specimens), or per gram of sediment. The latter quantity, devised by Schott (1935), is the Foraminiferal Number, the total number of individuals (both alive and dead) found in one gram of dry sediment. Relative abundances are usually expressed as the percentage of individuals (assigned to a particular species) of the total number of foraminiferids in the sample. The abundance chart supplied with this thesis (Appendix B, in pocket) measures absolute abundance of identified specimens. Either the Foraminiferal Number or the total number of foraminiferids on the slide is stated for each sample. This helps to show up differences in preservation (e.g. a high Foraminiferal Number and low specific counts would indicate poor preservation).

Diversity

Many mathematical quantities have been devised for measuring the diversity of biological assemblages. A good diversity index is one that takes all species present (however rare) into account along with the total sample

size. The Fisher alpha index fulfills these criteria well if the sample is not too large (alpha tends to increase at large sample sizes if the number of species is held constant). Fisher, Corbett, and Williams (1943) defined the alpha index as:

$a=N(1-x)/x$ where N=total number of individuals

x=a constant such that $1>x>0$

The use of the graph shown in figure 9 obviates the calculation of alpha for every sample.

In the abundance chart (in pocket), alpha has been given for each sample containing 100 or more individual foraminifers in an attempt to show up any microfacies. Suites with similar alpha indices and specific content might tend to form separate populations indicative of local facies control. In this study, no obvious microfacies are present, but a generally higher diversity is evident in the "Attachie" samples than in the others. Diversity may prove locally useful as a correlation tool in cases where specific content is inconclusive.

The low diversity of all the samples may also be a consequence of the solution of all calcareous tests. Since alpha indices as low as those observed are seldom obtained in living assemblages one may readily suspect post-mortem changes. Further, totally arenaceous life assemblages showing similar geographical ranges to these fossils are virtually unknown (as yet) today.

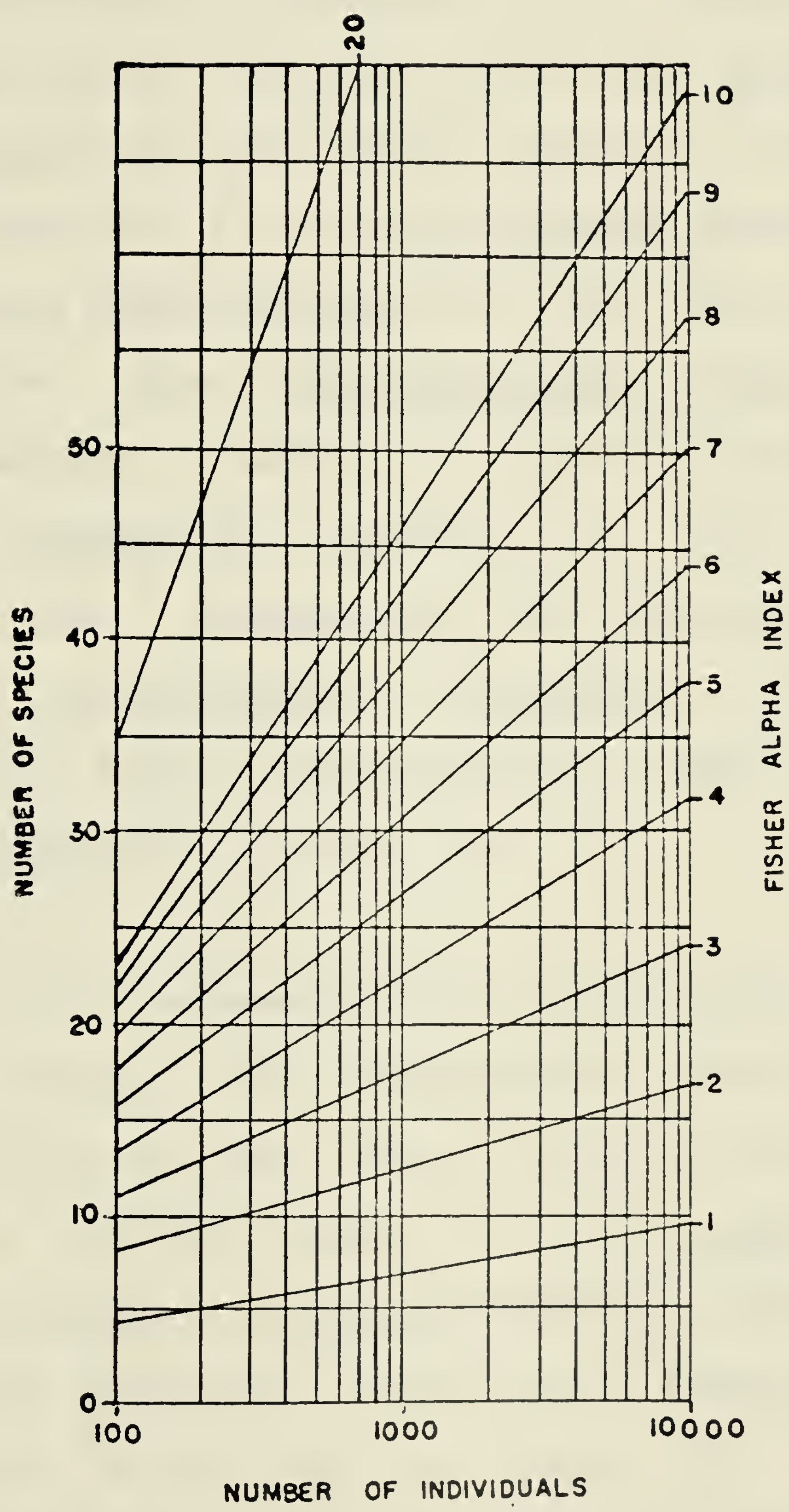

Figure 9 Chart useful for determining the Fisher alpha index (after Murray, 1973).

SUMMARY AND CONCLUSIONS

The 3 assemblages described in this thesis come from shales of the Hasler Formation between the *Gastroplites* and *Neogastroplites* Zones. The lowest ("Farrel") section comes from the upper part of the *Ammobaculites wenonahae* Subzone of the *Gaudryina nanashukensis* Zone. The "Attachie" suites represent the upper *Haplophragmoides gigas* Zone. The youngest assemblage ("Hasler") is from the lower part of the *Verneuilina canadensis* Subzone of the *Miliammina manitobensis* Zone. *Gastroplites* cf. *cantianus* occurs just below the *Ammobaculites wenonahae* Subzone and *Neogastroplites haasi* occurs in the upper part of the *Verneuilina canadensis* Subzone (fig. 6).

Figure 10 is a schematic cross-section over the Peace River Arch showing the relationships of the Foraminiferal faunas to the various rock units. It can be seen that the occurrence in British Columbia of the *H. gigas* equivalents *above* the *H. multiplum* fauna precludes any correlation of the Joli Fou Formation to the Harmon Member of the Peace River Formation. While this is clear, it is still not possible to positively date the Viking Formation due to a lack of diagnostic fossils. The "Viking-Cadotte" controversy cannot therefore be considered settled at this time. The new evidence presented in this thesis, however, makes it seem even less likely that the Viking Formation is of *Gastroplites* age.

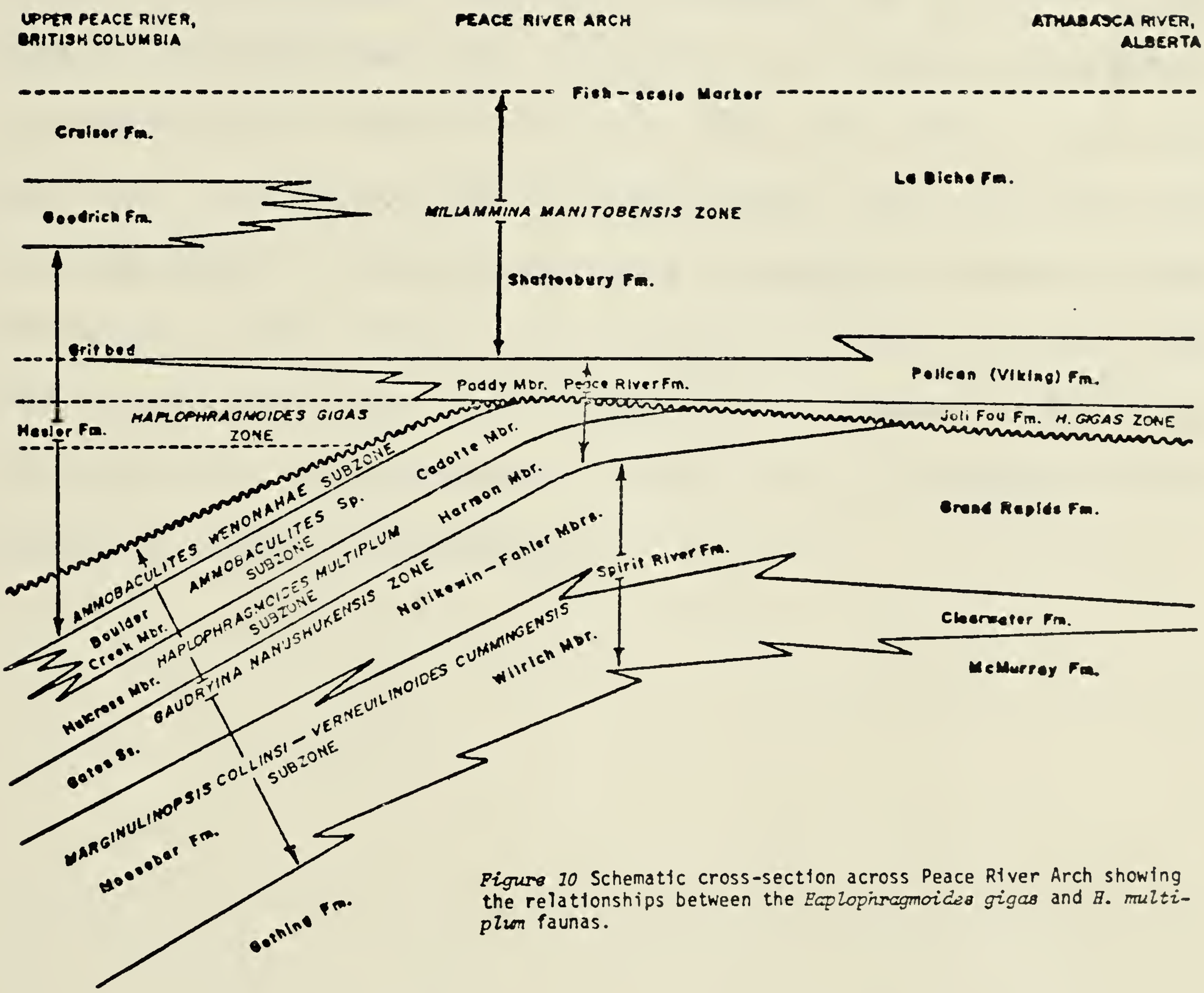

Figure 10 Schematic cross-section across Peace River Arch showing the relationships between the *Haplophragmoides gigas* and *H. multiplum* faunas.

The primary conclusions made after this study are: (1) the _Haplophragmoides_ _gigas_ Zone has been located for the first time in northeastern British Columbia, (2) the Albian sea during _H._ _gigas_ time had connections with the Arctic, from where this form probably migrated, (3) the Hasler sea invaded northeastern British Columbia to a point near present-day Williston Lake creating a "Hasler Embayment" northwest of the Peace River Arch (fig. 5), (4) the Joli Fou Formation (containing the _H._ _gigas_ fauna) and the Harmon and Hulcross Members (containing the _H._ _multiplum_ fauna) are _not_ equivalent (fig. 10), and (5) environmental factors which affect the gross aspect and calcareous content of living foraminiferal assemblages should be considered while analyzing fossil assemblages.

CHAPTER FIVE

SYSTEMATIC PALEONTOLOGY

Classification. The classification scheme followed in this thesis is that used by Loeblich and Tappan (1964). The descriptions use morphological terminology as defined by Loeblich and Tappan (1964, p. C58-C65). The accompanying illustrations are photographs of original camera lucida drawings by the author.

Stratigraphic sections. A detailed distribution chart showing the occurrence of species described herein is contained in Appendix B (in pocket). Corresponding lithologic descriptions and sampled horizons of the "Farrel", "Attachie", and "Hasler" sections are presented in Appendix A. Appendix C is a cross reference of thesis hypotype numbers and the sections and samples from which the hypotypes were chosen.

Dimensions. Normally, appropriate dimensions of 3 specimens will be given in each description if enough examples are available. A large and a small representative specimen of each form is included. All dimensions will refer to the maximum of the specimen (i. e. the maximum diameter). Dimensions given will take the form Length and Breadth (for elongate forms), Diameter and Thickness (for enrolled forms), or Length, Breadth, and Coil (applies to forms initially enrolled, later becoming elongate). "Coil" means

the maximum diameter of an early enrolled portion (primarily concerns *Ammobaculites* and *Haplophragmium*). Dimensions of other parameters (i. e. grain-size) will be given only when considered diagnostically important.

Type repository. All figured and unfigured thesis "type" specimens are stored in the Type Collections, University of Alberta. Figured hypotypes are denoted with an asterisk (*).

Order FORAMINIFERIDA Eichwald, 1830

Suborder TEXTULARIINA Delage and Herouard, 1896

Superfamily AMMODISCACEA Reuss, 1862

Family ASTRORHIZIDAE Brady, 1881

Subfamily RHIZAMMININAE Rhumbler, 1895

Genus *Bathysiphon* Sars, 1872

Bathysiphon brosgei Tappan, 1957

Plate 3, figures 1-3

1957. *Bathysiphon brosgei* Tappan, p. 202, pl. 65, figs. 1-5

1962. *Bathysiphon brosgei* Tappan, Tappan, p. 128, pl. 29, figs. 1-5

1968. *Bathysiphon brosgei* Tappan, Sliter, p. 39-40, pl. 1, fig. 1

1969. *Bathysiphon brosgei* Tappan, Mello, p. 40-41, pl. 4, fig. 1

1970. *Bathysiphon brosgei* Tappan, North and Caldwell, p. 13, pl. 1, fig. 3

1971. *Bathysiphon brosgei* Tappan, Morris, p. 263-264, pl. 1,

figs. 1-3

1971. Bathysiphon brosgei Tappan, Mello, p. C18-C19, pl. 1, figs. 7-9

1972. Bathysiphon brosgei Tappan, Sutherland and Stelck, p. 558, pl. 1, figs. 1,2

1975. Bathysiphon brosgei Tappan, Stelck, pl. 1, figs. 1-3

1975. Bathysiphon brosgei Tappan, North and Caldwell, pl. 6, fig. 2

1975. Bathysiphon cf. brosgei Tappan, North and Caldwell, pl. 1, fig. 1

1977. Bathysiphon brosgei Tappan, McNeil, p. 127-129, pl. 7, fig. 1

Description. Test free, small to large, elongate; a simple tube open at both ends, usually straight but sometimes bent, transverse growth ridges commonly present; wall finely agglutinated, smoothed with much cement; rounded openings are present at either end of the tube.

Types and occurrence. B. brosgei is confined to the "Attachie" section of this study and is never very common. Thesis hypotypes are: A1*, A2*, A3*, and A4.

Dimensions:

	Length	Breadth
Hypotype #A1*	1.04 mm	0.28 mm
Hypotype #A2*	1.02 mm	0.20 mm
Hypotype #A3*	0.72 mm	0.18 mm

Remarks. Although originally described from Albian to Campanian rocks in Alaska (Tappan, 1962), this species has been observed in many rocks ranging in age from Albian to Maestrichtian. Sutherland and Stelck (1972) recorded it from late Albian rocks in the Moberly Lake area, northeastern British Columbia, and Stelck (1975) identified it in the Buckinghorse Formation on the Sikanni Chief River, British Columbia. North and Caldwell (1975) noted this species (as *B*. *brosgei* and *B*. cf. *brosgei*) in Albian-Maestrichtian sequences in Saskatchewan and Manitoba. Morris (1971) recorded it in late Cretaceous rocks in Colorado and Sliter (1968) recovered this species from the Campanian-Maestrichtian Rosario Formation in southern California and adjoining Mexico.

In this study, *B*. *brosgei* is distinguished from *B*. *vitta* by its smaller size and its greater tendency to show growth constrictions and irregularities. ?*Hyperammina* alpha (this study) is distinguished from the present form by its thinner wall, normally smaller diameter, and the closure at initial end of the test.

Bathysiphon *vitta* Nauss, 1947

Plate 8, figure 1

1947. *Bathysiphon* *vitta* Nauss, p. 334, pl. 48, fig. 4

1960. *Bathysiphon* *vitta* Nauss, Trujillo, p. 302-303, pl. 43, figs. 2a,b

1960. _Bathysiphon_ _vitta_ Nauss, Takayanagi, p. 64-65, pl. 1, fig. 5

1962. _Bathysiphon_ _vitta_ Nauss, Tappan, p. 128-129, pl. 29, figs. 6-8

1963. _Bathysiphon_ _vitta_ Nauss, Graham and Church, p. 17-18, pl. 1, figs. 1a,b, 2a,b

1964. _Bathysiphon_ _vitta_ Nauss, North and Caldwell, p. 10-11, pl. 1, fig. 1

1967. _Bathysiphon_ _vitta_ Nauss, Wall, p. 38-39, pl. 7, figs. 4-7

1968. _Bathysiphon_ _vitta_ Nauss, Sliter, p. 40-41, pl. 1, fig. 3

1970. _Bathysiphon_ _vitta_ Nauss, North and Caldwell, p. 13-14, pl. 1, figs. 1, 2

1971. _Bathysiphon_ _vitta_ Nauss, Mello, p. C19-C20, pl. 1, fig. 10

1972. _Bathysiphon_ _vitta_ Nauss, Strong, p. 90, pl. 1, fig. 4

1975. _Bathysiphon_ _vitta_ Nauss, North and Caldwell, pl. 6, fig. 1

1977. _Bathysiphon_ _vitta_ Nauss, McNeil, p. 129-130, pl. 7, fig. 2

Description. Test free, large, elongate; composed of a single tubular chamber open at either end, usually compressed due to crushing; wall fairly thick, finely arenaceous and smoothly finished with much cement; apertures are simply the rounded open ends of the test.

Types and occurrence. This species occurs only in the "Hasler" section. It is not abundant. Thesis hypotypes are: A5*, A6-A9.

Dimensions:

	Length	Breadth
Hypotype #A5*	1.12 mm	0.60 mm
Hypotype #A6	1.28 mm	0.42 mm
Hypotype #A7	0.54 mm	0.42 mm

Remarks. Originally described from the Lea Park Formation (Campanian of Alberta), this species has since been noted in in beds ranging from Albian to Maestrichtian in age. It has been reported from most parts of western North America.

B. vitta has been described from Albian rocks in Alaska (Tappan, 1962), the Santonian Wapiabi Formation of Alberta (Wall, 1967), and from Campanian-Maestrichtian rocks in Saskatchewan and Manitoba (North and Caldwell, 1975). Mello (1971) found this species in Campanian rocks of the Pierre Shale, Wyoming, and Strong (1972) noted it in the Coniacian-Santonian part of the Marias River Shale also of Wyoming. In California and northwestern Mexico it has been described in beds ranging in age from Turonian to Campanian (Trujillo, 1960; Graham and Church, 1963; Sliter, 1968).

This species is distinguished in this thesis from B. brosgei by its larger size, generally more robust nature,

and shorter length relative to width. The black coating mentioned by Nauss (1947) in his original description was observed on only one specimen and is not here considered to be of diagnostic importance.

Subfamily HIPPOCREPININAE Rhumbler, 1895

Genus Hippocrepina Parker, 1870

Hippocrepina sp. A

Plate 1, figures 1, 2

Description. Test free, small, elongate to flask-shaped, tapers toward aperture, faint growth constrictions or incipient sutures may be visible, base may be narrow or broad, depending on preservation as the normally tapering, tube-like test may be crushed to an inflated shape reminiscent of Saccammina alexanderi; composed of a single chamber, not inflated; wall fine to medium arenaceous, color white, orange or amber; aperture rounded, terminal, produced after a well defined constriction in the test.

Types and occurrence. This species is rare and appears to be confined to the "Farrel" section. Thesis hypotypes are: B1*, B3*, B5, B6.

Dimensions:

	Length	Breadth
Hypotype #B1*	0.46 mm	0.14 mm
Hypotype #B3*	0.44 mm	0.14 mm

Hypotype #B5	0.44 mm	0.20 mm

Remarks. The present form is distinguished from _Hippocrepina_ cf. _barksdalei_ (Tappan) by its smaller, more coarsely agglutinated test. Also, _Hippocrepina_ sp. A does not have such a pronounced taper away from the aperture.

Hippocrepina sp. cf. _H_. _barksdalei_ (Tappan), 1962

Plate 3, figures 4, 5

1962. _Hyperamminoides_ _barksdalei_ Tappan, p. 129-130, pl. 29, figs. 22, 27

Description. Test free, medium, elongate, often flattened by crushing which may cause a central depression; composed of a single chamber with a flaring shape; wall finely agglutinated and smooth, probably originally somewhat flexible; aperture rounded, terminal, produced after a slight constriction of the test.

Types and occurrence. This species is restricted to the basal "Attachie" section. Thesis hypotypes are: B9*, C1*, C2.

Dimensions:

	Length	Breadth
Hypotype #B9*	0.70 mm	0.30 mm
Hypotype #C1*	0.54 mm	0.28 mm

Hypotype #C2 0.38 mm 0.24 mm

Remarks. This species conforms generally with Tappan's (1962) diagnosis for *H. barksdalei*. Her diagrams (1962, pl. 29, figs. 21-27) seem to include several forms which may represent more than one species. Figures 22 and 27 are identical with the present species.

Genus *Hyperammina* Brady, 1878

?*Hyperammina* sp. alpha

Plate 1, figures 3-5; Plate 3, figures 6, 8; Plate 8, figures 2-9

Description. Test free, medium, elongate; composed of a single tubular chamber closed at one end and often separated into two portions by a more or less pronounced constriction or incipient suture, only rarely is there a "bulbous proloculus"; wall finely agglutinated and smoothed with much cement; aperture rounded, terminal, often preceded by a faint constriction in the test.

Types and occurrence. This species occurs in all the sampled sections but is nowhere very common. Thesis hypotypes are: C3*-C8*, C9*, D1, D2, D3*, D4, D5*, D6, D7*, D8, D9*, E1, E2*, E3*, E4-E6.

Dimensions:

	Length	Breadth
Hypotype #C4*	0.68 mm	0.24 mm
Hypotype #D7*	0.44 mm	0.16 mm
Hypotype #E3*	0.32 mm	0.26 mm

Remarks. This species was first thought to belong to the genus *Bathysiphon* but was later transferred to *Hyperammina* when it was noticed that unbroken examples were rounded at one end and open at the other.

This species only seldom appears to have two chambers (the first being the proloculus) and therefore may not fall within *Hyperammina* sensu stricto.

Family SACCAMMINIDAE Brady, 1884

Subfamily PSAMMOSPHAERINAE Haeckel, 1894

Genus *Psammosphaera* Schulze, 1875

Psammosphaera sp.

Plate 1, figures 6-8, 11-13; Plate 3, figure 7; Plate 8, figures 10-13

1958. *Saccammina* sp. Stelck, Wall, and Wetter, p. 31, pl. 4, fig. 11

1971. *Saccammina* sp. Given and Wall, p. 522, pl. 2, figs. 8, 9

1972. *Saccammina* sp. C Sutherland and Stelck, p. 560-562, pl. 1, fig. 9

<u>Description</u>. Test free, tiny to small; composed of a single chamber, globular to ovate, commonly with a central depression due to crushing; wall finely agglutinated, smooth, thickness not determined; no aperture observed.

<u>Types and occurrence</u>. This species occurs throughout the three sampled sections but is generally rare. Thesis hypotypes are: E9*, F1-F3, F4*-F9*, G1*, G2, G3*-G5*, G6-G9.

Dimensions:

	Length	Breadth
Hypotype #E9*	0.20 mm	0.18 mm
Hypotype #F6*	0.40 mm	0.30 mm
Hypotype #F8*	0.18 mm	0.18 mm

<u>Remarks</u>. The present species was reported by Stelck, Wall, and Wetter (1956) from the "St. John Shale", the Dunvegan Formation, and the Shaftesbury Formation of Alberta. Given and Wall (1971) recorded it from the Bearpaw Formation of Alberta and Sutherland and Stelck (1972) identified it in the <u>Neogastroplites</u> zone near Moberly Lake in northeastern British Columbia.

This tiny foraminifer is present in many of the Cretaceous rocks of the western interior of Canada. It has previously been assigned to the arcellinid "thecamoebian" genus <u>Cyclopyxis</u> (<u>Leptodermella</u>), or to the genus <u>Saccammina</u>. It fits nicely in the genus <u>Psammosphaera</u>

because of its definitely siliceous arenaceous test and apparent lack of an aperture.

This species has been known for many years to the micropaleontologists of the University of Alberta--in fact it turns up in some of the early theses, usually as Leptodermella. The genus Psammosphaera is sufficiently broad to include tiny to medium forms without an aperture that possess varying pseudochitin to sand ratios and grain sizes.

Subfamily SACCAMMININAE Brady, 1884

Genus Saccammina Sars, 1864

Saccammina alexanderi (Loeblich and Tappan), 1950

Plate 1, figures 9, 10; Plate 3, figures 9, 10; Plate 8, figures 14, 15

1950. Proteonina alexanderi Loeblich and Tappan, p. 5, pl. 1, figs. 1, 2

1955. Proteonina cf. P. alexanderi Loeblich and Tappan, Stelck and Wall, p. 52-53, pl. 1, figs. 5, 6

1960. Saccammina alexanderi (Loeblich and Tappan), Eicher, p. 55, pl. 3, figs. 1, 2

1963. Saccammina alexanderi (Loeblich and Tappan), Crespin, p. 20-21, pl. 1, figs. 10-12

1965. Saccammina alexanderi (Loeblich and Tappan), Eicher, p. 891-892, pl. 103, fig. 1

1967. Saccammina alexanderi (Loeblich and Tappan), Eicher, p. 180, pl. 17, fig. 1

1967. Saccammina cf. alexanderi (Loeblich and Tappan), Guliov, p. 16-17, pl. 1, figs. 3a,b

1967. Saccammina cf. S. alexanderi (Loeblich and Tappan), Wall, p. 40-41, pl. 8, figs. 16, 17; pl. 14, figs. 17, 18

1970. Saccammina alexanderi (Loeblich and Tappan), North and Caldwell, p. 14-15, pl. 1, fig. 6

1970. Saccammina alexanderi (Loeblich and Tappan), Eicher and Worstell, p. 280, pl. 1, fig. 7

1971. Saccammina alexanderi (Loeblich and Tappan), Morris, p. 264, pl. 1, figs. 4, 5

1972. Saccammina alexanderi (Loeblich and Tappan), Sutherland and Stelck, p. 558-559, pl. 1, figs. 3, 4

1975. Saccammina alexanderi (Loeblich and Tappan), Stelck, pl. 1, figs. 21, 22

1975. Saccammina alexanderi (Loeblich and Tappan), North and Caldwell, pl. 1, fig. 4; pl. 6, fig. 6

1977. Saccammina alexanderi (Loeblich and Tappan), McNeil, p. 134-135, pl. 7, fig. 8

Description. Test free, small to large, most often medium sized; composed of a single chamber that is often pyriform or flask-shaped, usually compressed secondarily by crushing; wall thick, usually coarse to very coarsely agglutinated, typical grain-size (hypotype #H5*) is .01-.08mm; aperture rounded, terminal, produced on a short neck.

Types and occurrence. This species is common throughout the

"Attachie" and "Hasler" sections. It is present, but rare, in the "Farrel" section. Thesis hypotypes are: B2*, B4*, B7, B8, H1*, H2*, H3, H4, H5*, H6, H7, H8*, H9.

Dimensions:

	Length	Breadth
Hypotype #B4*	0.42 mm	0.20 mm
Hypotype #H1*	0.52 mm	0.38 mm
Hypotype #H8*	0.38 mm	0.30 mm

Remarks. Extremely simple test morphology makes it possible for the stratigraphic range of this species to extend from Albian to Campanian, thereby spanning much of the Cretaceous. It was first described by Loeblich and Tappan from the Kiowa Shale (Albian of Kansas). Occurrences of this species particularly relevant to this study include the Cenomanian-Turonian Kaskapau Formation of Alberta (Stelck and Wall, 1955), the Albian Thermopolis and Skull Creek Shales of Wyoming (Eicher, 1960), the Cenomanian Graneros Shale of Colorado and Wyoming (Eicher, 1965), the Cenomanian Belle Fourche Shale of Montana (Eicher, 1967), the H. gigas zone of Saskatchewan (S. cf. alexanderi of Guliov, 1967), Cretaceous rocks in the Foothills of Alberta (Wall, 1967), the late Cretaceous Bearpaw Formation of Saskatchewan (North and Caldwell, 1970), Albian rocks in northeastern British Columbia (Sutherland and Stelck, 1972; Stelck, 1975), and Albian-Cenomanian beds in Saskatchewan and Manitoba (North and Caldwell, 1975).

The present species is one of those forms that could have evolved independently many times throughout its stratigraphic range. The form described by Irene Crespin (1963) from Australia is morphologically identical to S. alexanderi (sensu Loeblich and Tappan) but these forms may well have derived from different ancestral stocks.

Saccammina lathrami Tappan, 1960

Plate 3, figures 11, 12; Plate 8, figures 16, 19, 20

1960. Saccammina lathrami Tappan, p. 289, pl. 1, figs. 1, 2

1962. Saccammina lathrami Tappan, Tappan, p. 129, pl. 29, figs. 9-12

1964. Saccammina lathrami Tappan, North and Caldwell, p. 11, pl. 1, fig. 3

1970. Saccammina lathrami Tappan, North and Caldwell, p. 15, pl. 1, fig. 4

1971. Saccammina lathrami Tappan, Morris, p. 264, pl. 1, figs. 6, 10

1975. Saccammina lathrami Tappan, North and Caldwell, pl. 1, fig. 5

Description. Test free, medium, robust if uncrushed; composed of a single chamber, originally inflated, often with a secondarily depressed central area due to crushing; wall often finely agglutinated, smooth to rough in texture; aperture rounded, terminal, produced on a neck that is often

broken off.

Types and occurrence. This species occurs abundantly to sporadically in the "Hasler" and "Attachie" sections. Thesis hypotypes are: I1*, I2, I3*-I5*, I6, I7*.

Dimensions:

	Length	Breadth
Hypotype #I1*	0.66 mm	0.46 mm
Hypotype #I4*	0.40 mm	0.46 mm
Hypotype #I7*	0.34 mm	0.30 mm

Remarks. Originally described from Alaskan rocks by Tappan (1960), this species has been found to occur in northern parts of the western interior of North America. It has been reported from the Lea Park and Bearpaw Formations of Saskatchewan (North and Caldwell, 1964, 1970) and the Albian-Cenomanian Lower Colorado Group and Ashville Formation by the same authors (1975). Morris (1971) noted it in the Upper Cretaceous Mancos Formation of Colorado.

McNeil (1977) points out that _S. complanata_ Franke is a very similar form and implies that _S. lathrami_ might be a junior synonym. They are here regarded as different forms. _S. lathrami_ is a boreal form which differs from _S. complanata_ in being smaller and in possessing a definite but shorter neck.

Subfamily DIFFUSILININAE Loeblich and Tappan, 1964

Genus *Thuramminoides* Plummer, 1945

Thuramminoides sp. cf. *T. septagonalis* Chamney, 1969

Plate 1, figures 15-18; Plate 8, figures 17, 18

Description. Test free, usually medium-sized, with an ovate, irregular, or polygonal outline (sometimes 7 sided); composed of a single chamber, probably originally inflated, usually distorted in preservation or with a central depression; wall finely to medium arenaceous, probably very thick-walled (no specimens are squashed completely flat), grey to whitish in color, usually smoothed with much cement; aperture(s) not characterized (a few specimens possess protruberances but it could not be determined whether these bear apertures).

Types and occurrence. This form occurs randomly in the "Farrel" and "Hasler" sections. It is moderately common to rare and usually turns up in the coarse meshes. Thesis hypotypes are: I8*, I9*, I19-I12, I14-I16, I17*, I18*, I19-I21, I22*, I23*, I24-I26.

Dimensions:

	Length	Breadth
Hypotype #I9*	0.66 mm	0.50 mm
Hypotype #I18*	0.56 mm	0.36 mm
Hypotype #I22*	0.66 mm	0.60 mm

Remarks. Chamney (1969, p. 14, pl. 1, figs. 8-11) described _T. septagonalis_ from the Lower Member of the Upper Shale-siltstone Division of the Mount Goodenough section, Barremian of the Northwest Territories. Later, Stelck (1975, pl. 1, figs. 11-13) figured this form from the Albian Sikanni Formation, northeastern British Columbia.

The present form, _T._ cf. _septagonalis_ differs from _T. septagonalis_ sensu stricto primarily in its increased intraspecific variation. For example, _T._ cf. _septagonalis_ is only occasionally 7 sided and is often highly distorted. Several specimens found in the "Farrel" section appear to be 2 fused individuals. Whether or not this configuration represents "fossilized plastogamy" is, of course, a matter of pure speculation.

Family AMMODISCIDAE Reuss, 1862

Subfamily AMMODISCINAE Reuss, 1862

Genus _Ammodiscus_ Reuss, 1862

Ammodiscus kiowensis Loeblich and Tappan, 1950

Plate 1, figures 14a,b; Plate 8, figure 21

1950. _Ammodiscus kiowensis_ Loeblich and Tappan, p. 5-6, pl. 1, figs. 3a,b

1956. _Ammodiscus kiowensis_ Loeblich and Tappan, Stelck, Wall, Bahan, and Martin, p. 25, pl. 5, figs. 16, 17

1960. _Involutina kiowensis_ (Loeblich and Tappan), Eicher, p. 55-56, pl. 3, fig. 3

1967. Ammodiscus kiowensis Loeblich and Tappan, Guliov, p. 18, pl. 1, figs. 7a,b

1975. Ammodiscus kiowensis Loeblich and Tappan, North and Caldwell, pl. 1, figs. 7a,b

1977. Ammodiscus kiowensis Loeblich and Tappan, McNeil, p. 142-143, pl. 7, fig. 14

Description. Test free, small, planispiral and usually flattened; composed of a proloculus (not observed) and a long tubular second chamber wound planispirally about it, initial coiling may be somewhat unstable (but never streptospiral); wall finely agglutinated, smooth; aperture not observed, but in crushed specimens the flattened terminal end of the second chamber may be visible (presumably the remains of the rounded aperture).

Types and occurrence. A. kiowensis is very rare in all sections sampled. Only 7 specimens were recovered. Thesis hypotypes are: J1*, J2, J3, J4*.

Dimensions:

	Diameter	Thickness
Hypotype #J1*	0.30 mm	0.04 mm
Hypotype #J2	0.32 mm	0.06 mm
Hypotype #J4*	0.20 mm	0.06 mm

Remarks. This species was first described from the Kiowa Shale (Loeblich and Tappan, 1950). It appears confined

strictly to Albian strata and has been reported from the Joli Fou Formation of Alberta (Stelck et al., 1956) and Saskatchewan (Guliov, 1967), the Thermopolis and Skull Creek Shales of Wyoming (Eicher, 1960), and the Albian rocks of the Lower Colorado Group and the Ashville Formation in Saskatchewan and Manitoba (North and Caldwell, 1975).

This species differs from _A. planus_ Loeblich and _A. mangusi_ (Tappan) in being more loosely planispiral with tendencies to adopt a _Glomospirella_-like habit. In their original description, Loeblich and Tappan (1950) state that although _A. kiowensis_ resembles _A. gaultinus_ Berthelin, the Kansas form is smaller and has a thinner coil.

?_Ammodiscus_ sp.

Plate 1, figures 19, 20

Description. Test free, often medium-sized, discoidal and flattened; composed of a proloculus (not observed) followed by a second, gradually expanding tubular chamber wound planispirally about the first chamber; wall fine to medium agglutinated, smooth or rough, color usually pale amber; aperture is the simple open end of the tube.

Types and occurrence. This species was found in the "Farrel" section. Only 4 easily identifiable examples were recovered. Thesis hypotypes are: J8*, J9*, J10, J11.

Dimensions:

	Diameter	Thickness
Hypotype #J8*	0.56 mm	0.06 mm
Hypotype #J9*	0.76 mm	0.10 mm
Hypotype #J10	0.60 mm	0.12 mm

Remarks. The present form bears a resemblance to *A. rotalarius* Loeblich and Tappan but it could not be assigned to that species with certainty because of poor preservation. Loeblich and Tappan's form was described from the Abian Walnut Clay of Oklahoma (1949). It has also been found in Albian rocks from Alaska (Tappan, 1962). Since the present form is Albian in age, it is possible that better preserved specimens might be referred to *A. rotalarius*.

Genus *Glomospira* Rzehak, 1888

Glomospira sp. cf. *G. reata* Eicher, 1960

Plate 8, figures 23, 24

Description. Test free, medium, flattened, early portion coiled streptospirally, later becoming almost planispiral, tending to include early whorls within the plane of the last 2 whorls (which are loosely planispiral); tubular second chamber slowly expanding at first, increasing rapidly in diameter over the last 2 whorls; sutures depressed, distinct to indistinct; wall agglutinated, medium grained, may be somewhat rough; aperture is the simple open end of the tube.

Types and occurrence. This species occurs in the "Hasler" section. Only 2 specimens were recovered. Thesis hypotypes are: J6*, J7*.

Dimensions:

	Diameter	Thickness
Hypotype #J6*	0.36 mm	0.12 mm
Hypotype #J7*	0.44 mm	0.08 mm

Remarks. The present species resembles closely *G. reata* Eicher in size, texture, and general shape. It has not been definitely assigned to Eicher's species because of poor preservation and limited material. The present species is the only streptospiral enrolled ammodiscid noted in this study.

Superfamily LITUOLACEA de Blainville, 1825

Family HORMOSINIDAE Haeckel, 1894

Subfamily HORMOSININAE Haeckel, 1894

Genus *Reophax* de Montfort, 1808

Reophax sp. cf. *R. eckernex* Vieaux, 1941

Plate 3, figures 13, 14; Plate 8, figures 25, 26

Description. Test free, large, robust, and elongate; chambers arranged in uniserial fashion, numbering 1 to 3 most commonly, rarely numbering 4, increasing very rapidly in size; sutures usually indistinct, meandering somewhat, often constricted; wall coarse to very coarsely

agglutinated, cement appears to incorporate many small silica particles; aperture terminal, produced on a stout, well defined neck.

Types and Occurrence. This species is found in both the "Attachie" and "Hasler" sections. It is moderately common, appearing mostly in the coarse screenings. Thesis hypotypes are: J12*, J13*, J14, J15, J16*, J17*, J18, J19.

Dimensions:

	Length	Breadth
Hypotype #J12*	0.96 mm	0.38 mm
Hypotype #J13*	0.70 mm	0.40 mm
Hypotype #J16*	0.80 mm	0.22 mm

Remarks. *R. eckernex* was described by Vieaux (1941) from the Lower Cretaceous Denton Formation of Texas. The present form differs from *R. eckernex* in having a much shorter neck and (usually) one less chamber. Also, the "acorn" appearance mentioned by Vieaux in his original description is not as well developed in the present form. *R. sikanniensis* Stelck is another species comparable to the present form. Stelck's form, however, has a peculiar build-up of cement about the neck and a hooked (sideways-pointing) aperture.

This species is easily distinguished in the study area by its large size, its coarse arenaceous texture, and its chambers which rapidly increase in size. One chambered

individuals (probably juveniles) are assigned to _Saccammina alexanderi_ in this thesis unless circumstances favour placing them in the present genus.

Family RZEHAKINIDAE Cushman, 1933

Genus _Miliammina_ Heron-Allen and Earland, 1930

Miliammina sp. cf. _M. awunensis_ Tappan, 1957

Plate 3, figures 15a,b; Plate 8, figures 27a,b

1962. _Miliamina awunensis_ Tappan, Tappan, p. 159-160, pl. 36, figs. 20, 21

1975. _Miliammina awunensis_ Tappan, Stelck, pl. 1, figs. 29, 30, 33-35

Description. Test free, medium to large, elongate, composed of tubular chambers wound in quinqueloculine fashion; chambers long, narrow, fairly uniform in diameter, each a half whorl in length; sutures distinct, depressed, may be fairly thick; wall finely arenaceous, smooth; aperture is the simple open end of the terminal chamber which often projects beyond the outline of the test.

Types and occurrence. This species is present in both the "Hasler" and "Attachie" sections. It is not common. Thesis hypotypes are: J34*, J35-J37, J48*, J49.

Dimensions:

	Length	Breadth
Hypotype #J34*	0.72 mm	0.28 mm
Hypotype #J35	0.62 mm	0.30 mm
Hypotype #J48*	0.58 mm	0.32 mm

Remarks. The present species in its strict sense was described from the Albian Grandstand, Tuktu, Topagoruk, Torok, and Chandler Formations of Alaska (Tappan, 1957). It has since been reported from Abian rocks in Alaska (Tappan, 1962) and from the *Miliammina manitobensis* zone in northeastern British Columbia (Stelck, 1975).

Tappan (1962) figured 5 specimens assigned to *M. awunensis*. The forms recovered in the present study are similar to 2 of these figured specimens, both of which are paratypes (Tappan, 1962, pl. 36, figs. 20, 21). The holotype of *M. awunensis* does not appear to belong to the present group. Wickenden (1932) described *M. manitobensis*, a form almost identical to the present species. Wickenden's form, however, is described from smaller specimens. The large, elongate forms here assigned to *M.* cf. *awunensis* have been separated for potential ecological analysis. There may well be a continuous spectrum of forms between the present species and *M. manitobensis* s. l.

Miliammina inflata Eicher, 1960

Plate 4, figures 1a,b; Plate 8, figures 22a,b

1960. *Miliammina inflata* Eicher, p. 70, pl. 5, figs. 13, 14

1966. *Miliammina ischnia* Tappan, Eicher, p. 21, pl. 4, figs. 5, 8

1967. *Miliammina ischnia* Tappan, Guliov, p. 21, pl. 3, figs. 2a-c

1972. *Miliammina inflata* Eicher, Sutherland and Stelck, p. 564, pl. 2, figs. 1, 2

1975. *Miliammina ischnia* Tappan, North and Caldwell, pl. 1, figs. 16a,b

Description. Test free, small, oval in outline even when uncrushed, long axis of test may appear slightly twisted; chambers medium length, tubular, inflated, may be wider near the middle than at the ends, each one-half whorl in length, wound in quinqueloculine fashion; sutures distinct, depressed, may appear to undulate in side view; wall finely arenaceous, usually smooth; aperture terminal, rounded, usually flush with end of test.

Types and occurrence. *M. inflata* is found in the "Hasler" and "Attachie" sections in the finer screenings. It is uncommon to rare. Thesis hypotypes are: J20*, J21-J24, J43*, J44-J47.

Dimensions:

	Length	Breadth
Hypotype #J20*	0.32 mm	0.20 mm
Hypotype #J21	0.40 mm	0.24 mm
Hypotype #J43*	0.34 mm	0.20 mm

Remarks. This species was originally described from the *Haplophragmoides gigas* zone of the Thermopolis Shale in Wyoming (Eicher, 1960). It has since been found in the Carlile Shale of Colorado (*M. ischnia* of Eicher, 1966), the *H. gigas* zone in Saskatchewan (*M. ischnia* of Guliov, 1967), the *Neogastroplites* zone of northeastern British Columbia (Sutherland and Stelck, 1972), and the Lower Colorado Group and Ashville Formation in Saskatchewan (*M. ischnia* of North and Caldwell, 1975).

M. inflata closely resembles *M. manitobensis* but does not seem to be subject to the variation (particularly in size) typical of the latter species. The present species is recognized by its small, inflated, ovate test (in three-dimensional, undistorted examples) and its common habit of appearing slightly twisted along the major axis.

<u>Miliamina</u> <u>ischnia</u> Tappan, 1957

Plate 4, figures 2a,b, 3a,b

1957. <u>Miliammina</u> <u>ischnia</u> Tappan, p. 211, pl. 67, figs. 25, 26

1960. <u>Miliammina</u> sp. cf. <u>M</u>. <u>sproulei</u> Nauss, Eicher, p. 72, pl. 5, figs. 17, 18

1962. <u>Miliammina</u> <u>ischnia</u> Tappan, Tappan, p. 160, pl. 37, figs. 1-5

1965. <u>Miliammina</u> <u>ischnia</u> Tappan, Eicher, p. 893, pl. 103, figs. 4, 5

1972. <u>Miliammina</u> <u>ischnia</u> Tappan, Sutherland and Stelck, p. 564-566, pl. 2, figs. 3-5

<u>Description</u>. Test free, small, elongate, sides sub-parallel when uncrushed, intact specimens may be triangular or quadrangular in cross-section; chambers long, narrow, and tubular, each one-half whorl in length, wound in quinqueloculine fashion; sutures distinct, depressed; wall finely agglutinated, usually smooth, often with a peculiar white and brown coloration due to the mode of preservation; aperture obscured, terminal on the ultimate chamber which may protrude beyond the end of the test (simulating a neck) or may be flush with the end of the test.

<u>Types</u> <u>and</u> <u>occurrence</u>. This species is found only in the "Attachie" section. It is rare to fairly common and turns up in the finer meshes of most samples. Thesis hypotypes are:

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

J25*, J26-J28, J29*, J30-J32.

Dimensions:

	Length	Breadth
Hypotype #J25*	0.30 mm	0.08 mm
Hypotype #J29*	0.30 mm	0.14 mm
Hypotype #J31	0.34 mm	0.08 mm

Remarks. This species has been reported from the Haplophragmoides gigas zone of the Thermopolis Shale of Wyoming (Eicher, 1960) and the Cenomanian Graneros Shale of Colcrado (Eicher, 1965). Sutherland and Stelck noted it in the Neogastroplites zone of northeastern British Columbia (1972). Tappan (1957) originally described it from Alaskan rocks.

The genus Miliammina is a difficult one to speciate, particularly when dealing with poorly preserved or crushed specimens. Tappan's original (1957) diagnosis for M. ischnia calls for a small test with subparallel sides and an elongate (rather than ovate) outline. In the past, many authors have assigned small, ovate specimens to the present species that more correctly belong in M. inflata Eicher. It should be noted that flattened specimens of this species often resemble examples of Psamminopelta. In this study, preservation style and coloration helped in the identification of this species.

It is interesting to note that M. sproulei is almost identical to the present species except for size. Nauss (1947) reports specimens of M. sproulei ranging in size from 0.27-0.9mm. The lower limit of this span is a typical size for M. ischnia. Since M. ischnia and M. sproulei are characteristically found in Albian rocks (often together in the Haplophragmoides gigas zone) it is possible that they may be conspecific. The name M. ischnia is retained for those populations composed of only small forms. If this variation in size is phenotypic, it is worthy of discrimination.

Miliammina manitobensis Wickenden, 1932

Plate 4, figures 4a,b, 5a,b; Plate 8, figures 28a,b

1932. Miliammina manitobensis Wickenden, p. 90, pl.1, figs. 11a-c

1946. Miliammina manitobensis Wickenden, Cushman, p. 48, pl. 14, figs. 4-6

1960. Miliammina manitobensis Wickenden, Eicher, p. 71, pl. 5, figs. 15, 16

1962. Miliammina manitobensis Wickenden, Tappan, p. 160, pl. 36, figs. 12-18

1965. Miliammina manitobensis Wickenden, Eicher, p. 893, pl. 103, figs. 8, 9

1967. Miliammina manitobensis Wickenden, Eicher, p. 180, pl. 17, fig. 5

1967. Miliammina manitobensis Wickenden, Wall, p. 47-48, pl.

1, figs. 1-6

1967. Miliammina cf. manitobensis Wickenden, Guliov, p. 22, pl. 3, figs. 3a,b

1972. Miliammina sp. cf. M. sproulei Nauss, Sutherland and Stelck, p. 566, pl. 2, figs. 6-9

1975. Miliammina manitobensis Wickenden, Stelck, pl. 1, figs. 31, 32

1975. Miliammina manitobensis Wickenden, North and Caldwell, pl. 1, figs. 12-14

1977. Miliammina manitobensis Wickenden, McNeil, p. 154-156, pl. 8, figs. 9-14

Description. Test free, small to large, ovate in outline and often flattened by crushing; chambers tubular, wound in quinqueloculine fashion, each one half whorl in length; sutures distinct, depressed, septa between chambers are less distinct or not visible; wall finely to medium arenaceous, usually smoothly finished with lots of cement; aperture rounded, the simple open end of the ultimate chamber, produced on the terminal end of the final chamber which often extends beyond the ovate outline of the test.

Types and occurrence. M. manitobensis occurs in the "Attachie" and "Hasler" sections. It is never very common in these samples. Thesis hypotypes are: J38*, J39-J42, J50*, J51*, J52.

Dimensions:

	Length	Breadth
Hypotype #J38*	0.50 mm	0.28 mm
Hypotype #J39	0.58 mm	0.30 mm
Hypotype #J51*	0.42 mm	0.22 mm

Remarks. Wickenden (1932) originally described M. manitobensis from the Ashville Formation of Manitoba. It has since been noted in the Albian Shell Creek (Eicher, 1960) and Mowry (ibid., 1965) Shales of Wyoming and in the Cenomanian Graneros and Frontier Formations (Eicher, 1967) also in Wyoming. Wall (1967) described it from the Albian basal Fort St. John Group and the Albian part of the Sunkay Member of the Blackstone Formation of Alberta. Stelck (1975) figured specimens from Albian beds in the Sikanni and Buckinghorse Formations of northeastern British Columbia. Guliov (1967) noted it in the H. gigas zone in Saskatchewan and North and Caldwell (1975) figure it from Albian-Cenomanian rocks in Saskatchewan and Manitoba. Tappan (1962) noted this species in the Albian Topagoruk and Grandstand Formations in Alaska.

In the sampled sections, Miliammina manitobensis is distinguished from other species of the genus by its size (usually larger than other forms), the usual presence of an apertural neck, and its broad, ovate outline. M. ischnia is smaller in the Attachie section, and is distinguished from M. manitobensis by its greater number of visible chambers

and its more constricted sutures.

Genus _Psamminopelta_ Tappan, 1957

Psamminopelta bowsheri Tappan, 1957

Plate 1, figures 21, 22; Plate 4, figure 9; Plate 9, figures 1, 2

1957. _Psamminopelta bowsheri_ Tappan, p. 11, pl. 6, figs. 11-18, 22-24

1962. _Psamminopelta bowsheri_ Tappan, Tappan, p. 157, pl. 37, figs. 11-22

1964. _Psamminopelta bowsheri_ Tappan, Loeblich and Tappan, p. C221-C222, fig. 133(6)

1965. _Spirolocammina bowsheri_ (Tappan), Eicher, p. 893, pl. 103, figs. 6, 10

1967. _Psamminopelta_ sp., Guliov, p. 23, pl. 3, figs. 4, 5

1972. _Psamminopelta bowsheri_ Tappan, Sutherland and Stelck, p. 556-557, pl. 2, figs. 14-17; pl. 3, figs. 1-4

1975. _Psamminopelta bowsheri_ Tappan, North and Caldwell, pl. 1, figs. 10a,b, 11

1977. _Psamminopelta bowsheri_ Tappan, McNeil, p. 157- 158, pl. 8, fig. 17

Description. Test free, ovate, flattened, planispiral; chambers tubular, long and narrow, each one-half coil in length, later chambers overlap previous ones; sutures distinct, depressed, often slightly thickened; wall fine to medium arenaceous, usually smoothed with much cement;

aperture the simple open end of the terminal chamber.

Types and occurrence. This species is rare to abundant in all sections sampled. It appears in almost every suite. Thesis hypotypes are: J53*, J54, J55, J56*, J57, J58*, J59, J60*, J61, J62, J63*, J64, J65.

Dimensions:

	Length	Breadth
Hypotype #J53*	0.34 mm	0.32 mm
Hypotype #J56*	0.50 mm	0.34 mm
Hypotype #J60*	0.42 mm	0.30 mm

Remarks. Orginally described by Tappan (1957) from Alaska, this species has since been found to occur in the Mowry and Graneros Shales in Colorado (Eicher, 1965), the Albian Joli Fou Formation of Saskatchewan (Guliov, 1967), the Albian beds of the Colorado Group and the Ashville Formation of Saskatchewan and Manitoba (North and Caldwell, 1975), and in northeastern British Columbia (Sutherland and Stelck, 1972). These rocks are all Albian or Cenomanian in age.

This genus is distinguished from Spirolocammina by its flat, planispiral test. There is only rarely (probably due to distortion) a twisted major axis in the present form.

Family LITUOLIDAE de Blainville, 1825

Subfamily HAPLOPHRAGMOIDINAE Maync, 1952

Genus Haplophragmoides Cushman, 1910

Haplophragmoides collyra Nauss, 1947

Plate 4, figures 6a-c

1947. Haplophragmoides collyra Nauss, p. 337-338, pl. 49, figs. 2a,b, 5

1958. Haplophragmoides collyra Nauss, LeRoy and Scheiltz, p. 2453, figs. 8 (11, 12)

1960. Haplophragmoides collyra Nauss, Wall, p. 16-17, pl. 3, figs. 16-19

1967. Haplophragmoides collyra Nauss, Eicher, p. 180-181, pl. 17, figs. 7, 9

1975. Haplophragmoides collyra Nauss, North and Caldwell, pl. 1, figs. 18a,b

1977. Haplophragmoides collyra Nauss, McNeil, p. 162-163, pl. 8, figs. 20a,b, 21a,b

Description. Test free, medium, robust when undistorted, planispiral with lobulate periphery; chambers inflated, numbering 7-9 in the outer whorl, increasing moderately in size, rather broad, imparting a robust appearance to the test; sutures distinct, depressed, radial or subradial in uncrushed specimens; wall finely agglutinated, neatly constructed with much cement, probably originally plastic (most specimens are crushed flat); aperture an interiomarginal arch at the base of the last chamber, with a

definite lip.

Types and occurrence. The "Attachie" and "Farrel" sections yielded several examples of this species. Thesis hypotypes are: L1*, L2-L4.

Dimensions:

	Diameter	Thickness
Hypotype #L1*	0.58 mm	0.36 mm
Hypotype #L3	0.56 mm	0.31 mm
Hypotype #L4	0.36 mm	0.24 mm

Remarks. This species has a stratigraphic range from Albian to Campanian. It was originally described from the Lloydminster Shale of east-central Alberta (Nauss, 1947); its geographic range has since been expanded to include much of the Canadian and American western interiors.

The present species seems to have its greatest development in Cenomanian rocks; Nauss' (1947) original description is probably from Cenomanian shales and Eicher (1967) recorded it from the Cenomanian Belle Fourche Shale of Wyoming, Colorado, and Montana. Wall (1960) describes it from the Turonian-Santonian rocks of the Kaskapau and Puskwaskau Formations of Alberta and North and Caldwell (1975) figured specimens from the Albian-Cenomanian Lower Colorado Group and Ashville Formation and Cenomanian-Campanian rocks in Saskatchewan and Manitoba. Leroy and

Scheiltz (1958) reported it in Campanian beds in the Pierre Shale, Colorado.

The specimens recovered in the present study conform well to Nauss' (1947) original description for _H._ _collyra_. The test is strongly inflated, usually has 7 or 8 chambers visible in the outer whorl, is clearly involute, and has straight sutures. _H._ cf. _H._ _collyra_ (sensu Stelck et al., 1956) from the _H._ _gigas_ zone in Alberta appears to be a juvenile of the present species. Slight limbation near the umbilicus of _H._ _collyra_ suggests a possible relationship with _H._ cf. _postis_ (this report). The prominent lip on the present form may prove to be diagnostic for the Lower Cretaceous members of this species.

Haplophragmoides _gigas_ Cushman, 1927

Plate 4, figures 7a-c, 8, 10a,b, 11

1927. _Haplophragmoides_ _gigas_ Cushman, p. 129-130, pl. 1, fig. 5

1946. _Haplophragmoides_ _gigas_ Cushman, p. 21, pl. 3, fig. 2

1947. _Haplophragmoides_ _gigas_ Cushman, Nauss, p. 338, pl. 49, figs. 8a,b

1956. _Haplophragmoides_ _gigas_ Cushman, Stelck, Wall, Bahan, and Martin, p. 35, pl. 5, fig. 1

1960. _Haplophragmoides_ _gigas_ Cushman, Eicher, p. 58, pl. 3, fig. 16

1967. _Haplophragmoides_ _gigas_ Cushman, Guliov, p. 23-24, pl.

[illegible]

4, figs. 1a-c

1969. <u>Haplophragmoides gigas</u> Cushman, Wickenden, p. 135-137, figs. 16a,b

1975. <u>Haplophragmoides gigas</u> Cushman, North and Caldwell, pl. 1 figs. 19a,b, 20a,b

1977. <u>Haplophragmoides gigas</u> Cushman, McNeil, p. 163-164, pl. 9, figs. 4a,b, 5

<u>Description</u>. Test free, planispiral, involute, almost always appearing compressed due to crushing, biumbilicate, periphery discoid to rounded, depending on extent of distortion; chambers 7 to 11 in final whorl, most often 8 to 10, triangular in side view, usually with a bulge in the umbilical region; sutures depressed, sigmoidal, may be somewhat thickened; wall finely arenaceous, often glazed with much cement; aperture a low interiomarginal arch at the base of the final chamber.

<u>Types and occurrence</u>. All examples of this species studied are from the "Attachie" section located near Attachie, British Columbia. Thesis hypotypes are: L5*, L6*, L7, L8*, L9*, L10-L15

Dimensions:

	Diameter	Thickness
Hypotype #L1*	0.66 mm	0.16 mm
Hypotype #L4*	0.50 mm	0.16 mm
Hypotype #L21*	0.30 mm	0.12 mm

Remarks. *H. gigas* was originally described by Cushman from Cretaceous rocks in Alberta. It has served well as a zone fossil characteristic of the Joli Fou Formation in Alberta and its equivalents in Saskathewan, Manitoba, and the United States. The occurrencé of *H. gigas* in northeastern British Columbia demonstrates the presence of Joli Fou Formation equivalents on the northwest side of the Peace River Arch.

H. gigas has been reported from unnamed Cretaceous rocks of Alberta (Cushman, 1927, 1946). Nauss (1947) described it from the Lloydminster Shale of Alberta, and Stelck et al. (1956) noted it in the Joli Fou Formation, also in Alberta. Guliov (1967) found this species in the Joli Fou Formation of Saskatchewan and North and Caldwell (1975) report it from the Lower Colorado Group and Ashville Formation of Saskatchewan and Manitoba. It has also been described from the Thermopolis and Skull Creek Shales of Wyoming by Eicher (1960). In addition, a form described as *Trochammina phaseolus* by Skolnick (1958) was synonymized by Eicher (1960) with the present form. It is not known to occur in strata other than Albian in age.

Specimens of *H. gigas* from the "Attachie" section have a smaller average diameter and often fewer visible chambers than many specimens figured in the literature. Large specimens with 10 or 11 chambers in the outer whorl are rare in the sampled section and found only near the base. Guliov (1967) and MacNeil (1977) both state that smaller specimens

predominate in the upper stratigraphic range of this species in Saskatchewan. These size variations have been attributed to undetermined changes in some environmental parameter.

This species is easily recognized by its involute test, characteristic sigmoid sutures, and the raised (umbonate) umbilical portions of the chambers. Even crushed or otherwise distorted specimens can usually be identified by the large, wedge-shaped ultimate chamber and the characteristic sigmoid sutures.

Haplophragmoides sp. cf. _H_. _gilberti_ Eicher, 1965

Plate 1, figures 24a,b, 25a,b, 26, 27a,b, 28a,b

Description. Test free, small to medium, planispiral evolute, composed of 3-4 whorls with 9-10 chambers in the final whorl, inner whorls often show a characteristic instability concerning the plane of coiling--the innermost whorl is usually skewed 5-30 degrees out of the plane of the outer whorl, peripheral margin lobulate; chambers numerous, inflated when uncrushed (periphery becomes rounded in damaged specimens); sutures distinct, usually depressed, gently curving or sinuate, often with a tiny forward-pointing "saddle" visible from the side; wall finely arenaceous, often smooth or glassy, color buff to orange; aperture not characterized, assumed interiomarginal.

Types and occurrence. This species is moderately common in

the "Farrel" section. Over 2 dozen specimens were recovered. Thesis hypotypes are: L46*-L48*, L49-L53, L54*, L55*, L56-L58.

Dimensions:

	Diameter	Thickness
Hypotype #L46*	0.30 mm	0.14 mm
Hypotype #L47*	0.34 mm	0.10 mm
Hypotype #L55*	0.32 mm	0.06 mm

Remarks. *Haplophragmoides gilberti* was first described by Eicher from the Cenomanian Graneros Shale of Colorado (1965). The same species was again identified by Eicher in the Cenomanian Frontier and Belle Fourche Formations of Wyoming and Montana (1967).

The present form differs from *H. gilberti* in having instability in the inner whorls and in having "saddles" on its sutures. *H. multiplum* Stelck and Wall has forward-pointing "saddles" on its sutures also, but lacks the instability of the inner whorls. Flattened specimens of the present species resemble *Trochamminoides apricarius* Eicher (see *T.* cf. *apricarius* in this report for discussion). It is not certain whether the instability observed in the inner whorls of this form is truly phenotypic or an artifact caused by crushing.

Haplophragmoides sp. cf. H. kirki Wickenden, 1932

Plate 1, figures 29a,b; Plate 4, figures 12a-c

1956. Haplophragmoides cf. H. kirki Wickenden, Stelck, Wall, Bahan, and Martin, p. 36, pl. 4, figs. 12, 13

1967. Haplophragmoides kirki Wickenden, Guliov, p. 24, pl. 4, figs. 2a,b

1975. Haplophragmoides cf. kirki Wickenden, North and Caldwell, pl. 2, figs. 1a-c

Description. Test free, small, robust, planispiral, fairly involute, with 4-6 chambers visible in the final whorl, peripheral margin usually somewhat lobulate; chambers inflated; wall finely agglutinated, often smooth; aperture not seen, assumed interiomarginal at the base of the ultimate chamber.

Types and occurrence. This form is found infrequently in both the "Farrel" and "Attachie" sections. It seems to have a random distribution in these sections. Thesis hypotypes are: L16*, L17-L20, L26*, L27-L30.

Dimensions:

	Diameter	Thickness
Hypotype #L16*	0.26 mm	0.18 mm
Hypotype #L26*	0.40 mm	0.24 mm
Hypotype #L29	0.26 mm	0.14 mm

Remarks. *H. kirki* Wickenden is an Upper Cretaceous species but the present form is found in Albian-Cenomanian rocks. Stelck et al. (1956) record it from the "St. John Shale" above the Gates Sandstone, Guliov (1967) reports it from the *Haplophragmoides gigas* zone in Saskatchewan, and North and Caldwell (1975) noted it in the Lower Colorado Group and the Ashville Formation is Saskatchewan and Manitoba.

Wickenden (1932) first described *H. kirki* from the Bearpaw Formation of Alberta. It has since been identified in rocks ranging in age from Albian to Maestrichtian. In this thesis, the Albian forms referred to *H.* cf. *kirki* are differentiated from *H. kirki* sensu stricto by their less inflated tests, smaller size, more lobulate periphery, and coarser texture. The classic *H. kirki* appears to be a strictly Upper Cretaceous form (see McNeil, 1977, p. 169-171 for a rational opinion).

Haplophragmoides linki Nauss, 1947

Plate 9, figures 3a,b

1927. *Haplophragmoides rugosa* Cushman and Waters, Cushman, p. 128-129, pl. 1, fig. 2

1947. *Haplophragmoides linki* Nauss, p. 339, pl. 49, figs. 7a,b

1956. *Haplophragmoides linki* Nauss, Stelck, Wall, Bahan, and Martin, p. 36-37, pl. 4, figs. 17, 18; pl. 5, figs. 5, 6

1960. Alveophragmium linki (Nauss), Eicher, p. 59-60, pl. 3, figs. 9-11

1967. Haplophragmoides linki Nauss, Guliov, p. 25, pl. 4, figs. 3a,b

1971. Haplophragmoides linki Nauss, Morris, p. 267-268, pl. 2, fig. 11

1975. Haplophragmoides linki Nauss, North and Caldwell, pl. 1, figs. 17a,b

1977. Haplophragmoides linki Nauss, McNeil, p. 171-172, pl. 9, figs. 1a,b

Description. Test free, fairly small, planispiral, involute with 7 or 8 chambers in the final whorl, periphery rounded or somewhat lobulate, deeply unbilicate; chambers distinct, increasing very gradually in size; sutures distinct, slightly depressed, may be thickened, radial; wall finely arenaceous, smooth with much cement; aperture interiomarginal, a low slit at the base of the ultimate chamber.

Types and occurrence. This species occurs only in the "Hasler" section where it is very rare. A unique cherry-red color is present in the interiors of the hypotypes. Thesis hypctypes are: L31*, L32-L35.

Dimensions:

	Diameter	Thickness
Hypotype #L31*	0.26 mm	0.12 mm
Hypotype #L32	0.26 mm	0.12 mm
Hypotype #L33	0.28 mm	0.14 mm

Remarks. This species was first described as *H. rugosa* by Cushman in 1927 and has been found only in the western interior of North America. Nauss (1947) placed *H. rugosa* into synonymy with his specimens found in the Albian Lower Lloydminster shale. Morris (1971) noted it in Upper Cretaceous rocks from northwestern Colorado and Eicher (1960) identified it (as *Alveophragmium linki*) in the Albian Thermopolis and Skull Creek Shales of Wyoming. Stelck et al. (1956) records it from the Albian Joli Fou Formation and "St. John Shales" of Alberta and northeastern British Columbia and Guliov (1967) found it in equivalent beds of the Joli Fou Formation in Saskatchewan. North and Caldwell (1975) figure specimens from the Mannville and Lower Colorado Groups and the Ashville Formation in Saskatchewan and Manitoba.

H. linki is readily distinguished from other species by its rounded to sub-rounded periphery, deep umbilicus and radial sutures. Specimens of *H.* cf. *postis* (this report) may resemble the present species superficially but they have "saddles" on their sutures and a more lobulate periphery. The form figured by Stelck (1975) as *H.* cf. *linki* lacks the

thickened sutures of the present form and the type (Nauss, 1947).

Haplophragmoides sp. cf. H. postis Stelck and Wall, 1956
Plate 4, figures 13a,b; Plate 5, figures 1-5; Plate 9,
figures 4-12

Description. Test free, small or medium sized, robust but often compressed or crushed by sediment, planispiral, becoming more evolute as growth progresses, bi-umbilical with parts of earlier whorls visible, usually 8-10 chambers visible in the outer whorl, fewer in inner whorls and on juveniles; chambers inflated, increasing gradually in size; sutures radial with a forward-pointing median "saddle" visible from each side of the test (this "saddle" may be obscured in larger specimens where it represents an internal feature), irregularly limbate towards the umbilicus, the limbation fading laterally and becoming depressed across the venter; wall finely agglutinated, usually smooth, often showing pyritized or opaque white to buff interiors of chambers; aperture interiomarginal, a high arch at the base of the last chamber, with a lip (this high arch and accompanying lip may later form the sutural "saddles").

Types and occurrence. This distinctive species is found in both the "Attachie" and "Hasler" sections. It is partcularly common in the "Hasler" sequence. Thesis hypotypes are: K1*, K2-K5, K6*-K9*, K11-K14, K15*-K18*, K19-K22, K23*-K28*, K29,

K30, L36*, L37-L39.

Dimensions:

	Diameter	Thickness
Hypotype #K23*	0.62 mm	0.26 mm
Hypotype #K25*	0.44 mm	0.20 mm
Hypotype #K36*	0.28 mm	0.12 mm

Remarks. H. postis Stelck and Wall (Stelck et al., 1956) and H. postis goodrichi Sutherland and Stelck (1972) both resemble H. cf. postis but descriptions of these subspecies make no mention of the characteristic sutures of the present form. H. topagorukensis Tappan is also simlar to H. cf. postis but is generally larger, lacks sutural "saddles", and shows more intraspecific variation (i. e. number of chambers in final whorl is highly variable in the Alaskan species). Large specimens of H. cf. postis were at first referred to H. topagorukensis until it was realized that the largest examples of H. cf. postis have an internal forward pointing "saddle" within each chamber.

H. multiplum Stelck and Wall is similar to very small specimens of the present species that have 10-12 chambers in the outer whorl and are unusually involute. However, only a small percentage of these tiny forms could be assigned with certainty to H. multiplum. Since intermediate forms fill in the entire spectrum between H. cf. postis and fossils resembling H. multiplum, these small specimens are

considered to represent aberrant examples (or many chambered juveniles) of the present species.

Haplophragmoides sp.

Plate 1, figures 23a,b

Description. Test free, small to medium large, planispiral enrolled with 6 to 8 chambers visible in outer whorl; chambers inflated, usually subglobular, often collapsed by burial compression suggesting an elastic construction; sutures distinct, depressed, usually straight and radial; wall finely to medium agglutinated, amber to whitish in color; aperture a low interiomarginal arch at the base of the ultimate chamber.

Types and occurrence. This form is best expressed in the "Farrel" section. Thesis hypotypes are: L21*, L22-25.

Dimensions:

	Diameter	Thickness
Hypotype #L21*	0.28 mm	0.16 mm
Hypotype #L22	0.38 mm	0.13 mm
Hypotype #L23	0.46 mm	0.16 mm

Remarks. This form is rarely preserved well enough for accurate characterization. It comprises a large population of mostly crushed planispiral forms occurring in the 80 and 100 mesh screenings. It is distinguished from *H. gilberti* by

its fewer number of chambers in the final whorl. _H_. _collyra_ is typically larger. Forms identical to both _H_. cf. _kirki_ and _H_. _linki_ are found within this group. The continuous intergradation between forms has convinced the author that he is dealing with a discrete group that connot be further subdivided on the basis of the number of chambers in the outer whorl.

On the basis of mesh size alone, it is tempting to divide the present species into two types: a population of small specimens occurs in the 100 mesh and appears identical to _H_. cf. _kirki_ while larger forms (in the 80 mesh fraction) are similar to _H_. _linki_ but with typically fewer chambers in the ultimate whorl. Since large numbers of individuals occur in both the 80 and 100 mesh, it is not unreasonable to suggest that the smaller forms represent the megalospheric phase while the larger variety is the microsphere. If these larger, identical forms were not present, it would be convenient to classify the 100 mesh specimens as _H_. cf. _kirki_ in the sense of North and Caldwell (1975, pl. 2, fig. 1a-c).

Genus Trochamminoides Cushman, 1910

Trochamminoides sp. cf. T. apricarius Eicher, 1965

Plate 5, figures 9a,b, 10

1972. Haplophragmoides gilberti Eicher, Sutherland and Stelck, p. 567-568, pl. 3, figs. 8, 9

1972. Trochamminoides apricarius Eicher, Sutherland and Stelck, p. 572, pl. 3, figs. 5-7

Description. Test free, small, compressed, planispiral and evolute, composed of 2 to 2 and one-half whorls of chambers with about 7 or 8 in the final whorl, peripheral margin often lobulate; chambers inflated, usually rounded; sutures distinct, depressed, radial to oblique, most often straight or gently curved; wall finely agglutinated, moderately smooth; aperture not observed, assumed interiomarginal at the base of the final chamber.

Types and occurrence. This species is fairly uncommon and occurs only in the "Attachie" section. Many specimens are too poorly preserved for accurate identification. Thesis hypotypes are: L40, L41*, L42, L43*, L44, L45.

Dimensions:

	Diameter	Thickness
Hypotype #L40	0.26 mm	0.06 mm
Hypotype #L41*	0.30 mm	0.10 mm
Hypotype #L43*	0.24 mm	0.08 mm

Remarks. *T. apricarius* was first described by Eicher (1965) from the Cenomanian Graneros Shale of Wyoming. The same author later recorded *T. apricarius* from the Turonian Carlile Shale of Colorado and the Cenomanian Belle Fourche Shale of Montana (Eicher, 1967). Sutherland and Stelck (1972) figured forms very similar to *T.* cf. *apricarius* (as *Haplophragmoides gilberti* Eicher and *T. apricarius*) from the Albian *Neogastroplites* zone from northeastern British Columbia.

Sutherland and Stelck's (1972) forms, like *T.* cf. *apricarius*, appear to be intermediate in thickness between *H. gilberti* and *T. apricarius*. Earlier whorls are thin on the present form while late whorls approach the thickness of those typical of *H. gilberti*. There is probably a close relationship between *H. gilberti* and *T. apricarius* because they are found in the same strata. The present intermediate form tends to confirm this statement.

Subfamily LITUOLINAE de Blainville, 1825

Genus *Ammobaculites* Cushman, 1910

The genus *Ammobaculites* was originally defined by Cushman (1910) to include those forms having a planispiral coil followed by a uniserial portion. The test is inflated (round or ovate in cross-section), and the aperture is simple, rounded, and terminal, usually produced on a neck.

In western Canada many such forms exist, and names such as _Ammobaculites fragmentarius_, _A. humei_, _A. tyrrelli_, or perhaps others immediately come to mind. Many of these forms, however, sometimes show an instability of the initial coil. This "instability" may concern the evoluteness of the coil, or the style of coiling itself. In large groups of specimens, one often observes examples with partly or wholly streptospiral or trochospiral coils. In the Albian of northeastern British Columbia, the _A. tyrrelli_ group seems to be particularly susceptible to this condition.

Stelck and Hedinger (1976) described _Haplophragmium swareni_ from the Upper Albian Sully Formation of northeastern British Columbia. This species is very similar to aberrant examples of _A. tyrrelli_ that have streptospiral or trochospiral initial coils. _H. swareni_, however, usually has more chambers and possesses a unique characteristic--"secondary cribration". This term refers to a system of pores developed on the intercameral walls of the uniserial portion of _H. swareni_.

The preceding discussion and the results of the present study leads the author to conclude that there is a continuous series between species of _Ammobaculites_ and specimens more correctly referred to _Haplophragmium_. This may be a local phenomenon tied to environmental conditions, or it may be a more general trend in the evolution of these forms. More work in other localities and stratigraphic

horizons is needed to clarify the situation. It is interesting to speculate that a form similar to A. tyrrelli might be the ancestor of H. swareni. The instability of the coil in the "ancestral" form seems to increase throughout Albian time in northeastern British Columbia.

Another problem concerning the genus Ammobaculites in western Canada is the speciation of the A. fragmentarius group. A. humei, A. tyrrelli, and A. fragmentarius can all be described as distinct forms. However, there is usually intermediate specimens in suites containing 2 or more of these species. Two methods of approach have been tried by workers in the past: the 3 forms may be synonymized (eg. see Tappan, 1962) or they may be painstakingly classified according to morphotypes. In this study, every effort has been made to separate these forms. It should be noted, however, that these species have similar stratigraphic and geographic ranges. If environmental factors are considered, it is not unreasonable to speculate that they may represent identical genotypes.

Ammobaculites culmula Skolnick, 1958

Plate 5, figure 6

1958. Ammobaculites culmula Skolnick, p. 280, pl. 37, figs. 2a-c

1975. Ammobaculites petilus Eicher, North and Caldwell, pl. 2, figs. 6, 7

[illegible]

[illegible]

[illegible]

[illegible]

1977. Ammobaculites petilus Eicher, McNeil, p. 181, pl. 10, fig. 8

Description. Test free, small to medium, elongate, composed of an initial coil of about 5 visible chambers followed by a uniserial portion of about 3-6 chambers; chambers slightly wider than high in uniserial part, probably originally inflated, increasing only slightly or not at all in diameter towards aperture; sutures distinct, depressed, thickened; wall medium agglutinated, rough; aperture terminal, originally rounded, produced on a short neck.

Types and occurrence. This form is very rare in the "Attachie" section. Thesis hypotypes are: 40*, 41.

Dimensions:

	Coil	Length	Breadth
Hypotype #40*	0.14 mm	0.60 mm	0.16 mm
Hypotype #41	0.16 mm	0.42 mm	0.16 mm

Remarks. This species was first decribed by Skolnick from the Albian Skull Creek Shale of the Black Hills region. Eicher (1960) figured a very similar form from Albian rocks in Wyoming. The latter species, A. petilus, has an Ammobaculoides-like development in the test immediately after the coil. A. petilus was identified by Guliov (1967) in the Joli Fou Formation of Saskatchewan. The form described as A. petilus by McNeil (1977) from the Albian

Skull Creek Member of the Ashville Formation of Saskatchewan appears to belong to A. culmula. The specimens figured by North and Caldwell as A. petilus (1975b, pl. 2, figs. 6,7) from the Albian Lower Colorado Group and Ashville Formations of Saskatchewan belong to the present species as they lack the initial biserial portion immediately after the coil.

A. culmula is easily identified by its slender test and rough wall. The present form shows no tendency to insert a biserial portion between the coil and and uniserial part.

Ammobaculites fragmentarius Cushman, 1927

Plate 2, figure 1; Plate 5, figures 7, 8, 11; Plate 9, figures 13, 14

1927. Ammobaculites fragmentaria Cushman, p. 130, pl. 1, fig. 8

1927. Ammobaculites coprolithiforme Schwager, Cushman, p. 130, pl. 1, fig. 7

1956. Ammobaculites fragmentarius Cushman, Stelck, Wall, Bahan, and Martin, p. 21-22, pl. 5, figs. 18, 19

1956. Ammobaculites fragmentarius variety, Stelck, Wall, Bahan, and Martin, p. 22, pl. 5, fig. 19

1960. Ammobaculites fragmentarius Cushman, Eicher, p. 61-62, pl. 4, fig. 11

1962. Ammobaculites fragmentarius Cushman, Tappan, p. 136-138, pl. 32, figs. 10, 11

1963. Ammobaculites fragmentarius Cushman, Crespin, p. 39,

pl. 7, fig. 15

1967. Ammobaculites fragmentarius Cushman, Wall, p. 55, pl. 1, figs. 7-9; pl. 7, figs. 18-20

1971. Ammobaculites fragmentarius Cushman, Morris, p. 269, pl. 3, figs. 1,2

1975. Ammobaculites fragmentarius Cushman, Stelck, pl. 2, figs. 21-23, 25-27; pl. 3, figs. 1, 2, 15

1975. Ammobaculites fragmentarius Cushman, North and Caldwell, pl. 2, figs. 2-5

1977. Ammobaculites fragmentarius Cushman, McNeil, p. 178-181, pl. 10, figs. 6, 7

Description. Test free, elongate, subcylindrical in intact specimens, composed of a relatively small initial planispiral coil of 3 to 5 chambers followed by a uniserial portion of about 5 chambers; chambers inflated, usually broader than long, often increasing in size to impart a flaring appearance to the test, ultimate chamber may be pyriform; sutures depressed, distinct on finely agglutinated examples to indistinct on coarse textured specimens; wall finely to coarsely arenaceous; aperture terminal, rounded, often with a slight neck.

Types and occurrence. This species occurs in all three of the studied sections. It appears to be widepread in both stratigraphic and geographic range in the study area. Thesis hypotypes are: 25*, 26*, 27, 28, 29*, 30*, 31-35, 36*, 37-39, 42*, 43-45.

Dimensions:

	Coil	Length	Breadth
Hypotype #25*	0.16 mm	0.62 mm	0.34 mm
Hypotype #29*	0.14 mm	0.70 mm	0.22 mm
Hypotype #36*	0.18 mm	0.68 mm	0.24 mm

Remarks. *A. fragmentarius* was first described by Cushman from Cretaceous rocks in western Canada. He subsequently figured (Cushman, 1956) forms from the Gulf Coast region and Trinidad (as *A. coprolithiforme* from Trinidad) that are assignable to this species. The boreal form, however, is the one dealt with in this thesis.

Stelck et al. (1956) reported this species from the Albian Joli Fou Formation of Alberta. It is in Albian beds of the Sikanni and Buckinghorse Formations in northeastern British Columbia (Stelck, 1975). It has been identified in the Joli Fou Formation of Saskatchewan (Guliov, 1967), the basal beds of the Fort St. John Group in Alberta (Wall, 1967), and the lower part of the Lower Colorado Group and the Ashville Formation in Saskatchewan and Manitoba (North and Caldwell, 1975). Outside Canada, it has been reported from the Albian Thermopolis and Skull Creek Shales of Wyoming (Eicher, 1960), from Albian rocks in Alaska (Tappan, 1962) and from Cretaceous rocks in Australia (Crespin, 1963).

There has been a general movement in the literature to

synonymize many species of Ammobaculites with the present one (see especially Tappan, 1962; McNeil, 1977). After a study of their discussions, the author concludes that A. humei Nauss (1947) may be a variant of A. fragmentarius. The possibility exists that the two species could form a dimorphic pair: the microsphere would be A. fragmentarius and A. humei could be the megalosphere.

Eicher (1960) placed a number of forms described by Skolnick (1958) into synonymy with A. euides which, in turn, was classified with A. fragmentarius by McNeil (1977). Normally, A. euides has broken sutures on the coiled part, a characteristic not shown by A. fragmentarius. They are not herein considered to be conspecific.

A. fragmentarius Cushman has been applied to a large number of morphotypes by Canadian and American authors. In this study, use of this name is restricted to examples of Ammobaculites with a small initial coil that flare more or less towards the aperture. Specimens assigned to this species are usually coarsely agglutinated and must have a planispiral initial coil.

Ammobaculites fragmentarius Cushman variety

Plate 5, figures 12, 13a,b; Plate 6, figures 1a,b; Plate 9, figures 15, 16

1967. *Ammobaculites fragmentarius* Cushman variety, Guliov, p. 27-28, pl. 5, figs. 1a,b

1975. *Ammobaculites fragmentarius* Cushman, North and Caldwell, pl. 2, fig. 2

Description. Test free, medium, elongate, early portion loosely planispiral (rarely streptospiral) of about 4 chambers, later part uniserial of 2-6 (usually 2-4) chambers, coil generally has a slightly lobulate (more so if crushed) periphery, coil is about the same diameter or larger than the first uniserial chamber and is fairly broad, sides subparallel; chambers medium inflated, may increase in size as added in uniserial part; sutures distinct, depressed, usually subparallel, often curved or undulating; wall medium arenaceous, well constructed with much cement; aperture terminal, rounded, produced on a short neck.

Types and occurrence. This form occurs in the "Attachie" and "Hasler" sections. Thesis hypotypes are: 6*, 7*, 8-10, 55, 56*, 57*, 58-60, 69*, 70-72.

Dimensions:

	Coil	Length	Breadth
Hypotype #7*	0.20 mm	0.64 mm	0.30 mm
Hypotype #56*	0.20 mm	0.80 mm	0.24 mm
Hypotype #57*	0.22 mm	0.82 mm	0.32 mm

Remarks. The present form is very similar to A. fragmentarius except that the test may not flare towards the apertural end. A. fragmentarius variety usually has fewer chambers in the coil than the species s. s. and has a broader coil. The present form can be distinguished from A. cf. humei by its normally greater number of chambers. A. wenonahae usually has fewer chambers, a more lobulate periphery, and is generally broader.

The present form somewhat resembles A. euides Loeblich and Tappan, a species reported from the Albian Kiamichi and Walnut Formations of Oklahoma and Texas (Loeblich and Tappan, 1949, 1950). A. euides was subsequently identified in the Haplophragmoides gigas zone of Wyoming (Eicher, 1960) and Saskatchewan (Guliov, 1967). The present form, however, lacks the characteristic broken sutures present on the coil of A. euides. (see Eicher, 1960).

Ammobaculites sp. cf. *A. humei* Nauss, 1947

Plate 2, figures 2-4

Description. Test free, medium, equidimensional to elongate, robust, composed of a coil of about 5 chambers followed by 1-3 uniserial chambers, periphery lobulate; chambers inflated, often globular; sutures distinct, subparallel in uniserial part, often thickened (especially in umbilicus of coil); wall medium arenaceous, rough but well constructed and strong, usually white in color; aperture rounded, terminal, fairly large, produced on a well defined neck.

Types and occurrence. This form is found in the "Farrel" section. Thesis hypotypes are: 11*, 12-15, 20*, 21*, 22-24.

Dimensions:

	Coil	Length	Breadth
Hypotype #11*	0.30 mm	0.44 mm	0.26 mm
Hypotype #20*	0.20 mm	0.60 mm	0.22 mm
Hypotype #21*	0.26 mm	0.64 mm	0.24 mm

Remarks. *A. humei* Nauss sensu stricto was described from the Cummings Member of the Mannnville Formation near Vermillion, Alberta. The present form is herein compared to that species because both forms have broad coils and parallel-sided tests. *A.* cf. *humei*, however, has markedly fewer chambers.

The present form is fairly distinct in the "Farrel"

section. It can be distinguished from _A_. _fragmentarius_ and _A_. _fragmentarius_ variety by its larger coil and fewer uniserial chambers. _A_. _tyrrelli_ and related forms are significantly smaller. It is, however, possible that the present form could represent small, well preserved specimens of _A_. _wenonahae_. The large, usually flattened hypotypes of _A_. _wenonahae_ seem comparable in all respects except size.

Ammobaculites _tyrrelli_ Nauss, 1947

Plate 2, figures 5a,b, 6a,b

1927. _Ammobaculites_ _coprolithiforme_ Schwager, Cushman, p. 130, pl. 1, figs. 6, 7

1932. _Ammobaculites_ _coprolithiformis_ Schwager, Wickenden, p. 204-205, pl. 29, fig. 2

1947. _Ammobaculites_ _tyrrelli_ Nauss, p. 333, pl. 48, fig. 2

1956. _Ammobaculites_ _tyrrelli_ Nauss var. _jolifouensis_ Stelck and Wall, _in_ Stelck, Wall, Bahan, and Martin, p. 23-24, pl. 5, fig. 20

1960. _Ammobaculites_ _tyrrelli_ Nauss, Eicher, p. 64, pl. 4, fig. 1

1967. _Ammobaculites_ _tyrrelli_ Nauss, Guliov, p. 28-29, pl. 5, figs. 3a,b

1975. _Ammobaculites_ _tyrrelli_ Nauss, Stelck, pl. 2, figs. 28, 29

1975. _Ammobaculites_ _tyrrelli_ Nauss, North and Caldwell, pl. 2, figs. 8, 9

1977. _Ammobaculites_ _tyrrelli_ Nauss, McNeil, p. 183-184, pl.

10, figs. 9, 10

Description. Test free, small or medium, elongate, consisting of an initial coil of about 4 visible chambers followed by a uniserial portion also totalling about 4 chambers; chambers medium inflated, wider than high; sutures straight, parallel in uniserial part, radial in coil, may be thickened; wall fine to medium arenaceous, well constructed, often smooth; aperture terminal, rounded, produced on a neck that is often broken off.

Types and occurrence. This species is found in the "Farrel" section. Thesis hypotypes are: 76*, 77*, 78-80.

Dimensions:

	Coil	Length	Breadth
Hypotype #76*	0.18 mm	0.54 mm	0.18 mm
Hypotype #77*	0.16 mm	0.38 mm	0.16 mm
Hypotype #79	0.18 mm	0.48 mm	0.18 mm

Remarks. *Ammobaculites tyrrelli* was first described by Nauss (1947) from the lower Lloydminster shale in Alberta. Previously, it had been recorded from the Alberta Shale (as *A. coprolithiformis* Schwager by Wickenden, 1932) and from unnamed Cretaceous rocks of Alberta (as *A. coprolithiforme* Schwager by Cushman, 1927). It has also been noted in the Albian Joli Fou Formation of Alberta (Stelck et al., 1956) and Saskatchewan (Guliov, 1967), the Albian part of the

Lower Colorado Group and Ashville Formation of Saskatchewan (North and Caldwell, 1975), and the Albian Thermopolis and Skull Creek Shales of Wyoming (Eicher, 1960).

A. tyrrelli is distinguished in this study by its fairly small size, its straight sutures, and the sub-parallel sides of the test. A. cf. tyrrelli (this study) is more robust, has more inflated chambers, and often has undulating sutures. A. culmula is slender and has more uniserial chambers than A. tyrrelli.

Ammobaculites sp. cf. A. tyrrelli Nauss, 1947

Plate 9, figures 17a,b

Description. Test free, medium, robust, elongate, composed of an initial coil of about 4-5 chambers followed by a uniserial portion of 2-4 chambers; chambers inflated, wider than high or almost equidimensional, may be subglobular; sutures distinct, depressed, often thickened, undulating to parallel in uniserial part; wall fine to medium arenaceous, well constructed; aperture terminal, rounded, produced on a neck that is often broken off.

Types and occurrence. This form in found in the "Hasler" section. Thesis hypotypes are: 1*, 2-5.

Dimensions:

	Coil	Length	Breadth
Hypotype #1*	0.26 mm	0.64 mm	0.22 mm
Hypotype #2	0.24 mm	0.32 mm	0.18 mm
Hypotype #3	0.22 mm	0.56 mm	0.20 mm

Remarks. This form is nearly identical to A. tyrrelli in most respects. A. cf. tyrrelli, however, has a tendency to be larger, more robust, and more loosely constructed than the form s. s. The present form often has undulating sutures in the uniserial part and the sides of the test may be non-parallel. This effect seems to be caused by the more inflated condition of the uniserial chambers. The observed differences between A. tyrrelli and A. cf. tyrrelli could well be environmentally controlled.

Ammobaculites wenonahae Tappan, 1960

Plate 2, figures 7a,b, 8

1951. Ammobaculites tyrrelli Nauss, Tappan, p. 3, pl. 1, figs. 12-14

1960. Ammobaculites wenonahae Tappan, p. 291, pl. 1, figs. 3-6

1962. Ammobaculites wenonahae Tappan, Tappan, p. 138-139, pl. 32, figs. 1-7

Description. Test free, medium to large, elongate, robust when not crushed, early portion consists of a coil with

about 4-6 chambers visible, later stage is uniserial with about 2-6 chambers and nearly parallel sides, coil is equal to or greater in diameter than the first uniserial chamber and has a lobulate periphery; chambers probably originally inflated, equidimensional or low and broad in uniserial part; sutures distinct, depressed, usually subparallel except in very coarse examples; wall arenaceous, usually medium grained with much cement; aperture terminal, rounded, usually produced on a slight neck.

Types and occurrence. This species occurs in the "Farrel" section. Thesis hypctypes are: 16*, 17-19, 46, 47*, 48-50.

Dimensions:

	Coil	Length	Breadth
Hypotype #16*	0.24 mm	0.70 mm	0.28 mm
Hypotype #47	0.26 mm	0.50 mm	0.26 mm
Hypotype #48	0.54 mm	0.64 mm	0.42 mm

Remarks. This species has been previously recorded only from Alaska (Tappan, 1951, 1960, 1962) where it occurs in the Albian Torok, Topagoruk, Grandstand, and Kukpowruk Formations. A very similar species, the *A. euides* of Skolnick (1958), Eicher (1960), and Guliov (1967) occurs in Albian rocks and co-exists with *Haplophragmoides gigas* in Wyoming and Saskatchewan (see Eicher, 1960, and Guliov, 1967). Probably the major difference between these forms is the presence of broken sutures on the venter of the coil of

[illegible]

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

A. euides.

This species is distinguished by the robust nature of the coil and parallel sides on the uniserial part. In this respect it resembles A. tyrrelli, but the latter species is smaller, has fewer chambers, and lacks the lobate periphery of the coil that characterizes A. wenonahae. A. cf. humei is generally smaller and more robust than the present form. These differences, however, may not represent corresponding differences in genotypes.

Genus Ammomarginulina Weisner, 1931

Ammomarginulina cragini Loeblich and Tappan, 1950

Plate 6, figures 2a,b, 3, 4a,b

1950. Ammomarginulina cragini Loeblich and Tappan, p. 6, pl. 1, figs. 4-6

1960. Ammomarginulina cragini Loeblich and Tappan, Eicher, p. 60-61, pl. 3, fig. 20

Description. Test free, medium to very large, compressed, planispiral evolute, composed of 1-3 whorls of chambers followed by 1 uniserial chamber, about 7 chambers in ultimate whorl, peripheral outline may be faintly polygonal; chambers indistinct, not inflated; sutures very indistinct, appressed, usually straight, radial; wall coarse or medium arenaceous, amber to brown in color, seldom smooth; aperture terminal, produced on a neck thereby giving the final chamber a somewhat pyriform shape.

Types and occurrence. This species is found in the "Attachie" section where it is rare. One example of *A. cragini* is the single largest foraminifer recovered in this study. Thesis hypotypes are: 51*-53*, 54.

Dimensions:

	Diameter	Thickness
Hypotype #51*	1.28 mm	0.26 mm
Hypotype #52*	0.58 mm	0.20 mm
Hypotype #53*	0.42 mm	0.10 mm

Remarks. *A. cragini* was first described by Loeblich and Tappan (1950) from the Kiowa Shale in Kansas. Eicher (1960) noted it in the *H. gigas* zone of the Thermopolis Shale of Wyoming. The same author found a related species (*A. paterella* Eicher, 1967) in the Cenomanian Belle Fourche Shale of Montana (1967). Stelck (1975) identified a similar form (as *Ammomarginulina*? cf. *A. paterella*) in the Albian beds of the Buckinghorse Formation in northeastern British Columbia.

A. cragini is easily identified by its coarse texture, evolute coiling, and terminal aperture. In this study, no specimens displayed more than one "uniserial" chamber. *A. paterella* Eicher differs from *A. cragini* Loeblich and Tappan in its more involute coiling and greater tendency to add uniserial chambers to the test. Illustrations of the types (Loeblich and Tappan, 1950) seem to include a wide range of

forms (ibid. pl. 1, figs. 4-6). Megalospheric-microspheric dimorphism could perhaps account for this wide variation. The forms recovered in this study resemble what appears to be a microspheric type (ibid. pl. 1, fig. 6). A. paterella Eicher seems to have affinities to the megalospheres(?) of the present species (Loeblich and Tappan, 1950, pl. 1, figs. 4a, b, 5).

Genus Haplophragmium Reuss, 1860

Haplophragmium sp. cf. H. swareni Stelck and Hedinger, 1976

Plate 9, figures 18a,b, 19, 20

Description. Test free, small, elongate, composed of a streptospiral initial coil of at least 4 chambers followed by a uniserial part of about 4 chambers, sides of test parallel; chambers moderately inflated, wider than high in uniserial portion; sutures usually straight, parallel in uniserial part, often thickened (especially in coil); wall fine arenaceous, smoothed with much cement; aperture terminal, rounded, short neck usually broken off.

Types and occurrence. This species is found in the "Hasler" section. Thesis hypctypes are: 73*, 74*, 75*.

Dimensions:

	Coil	Length	Breadth
Hypotype #73*	0.20 mm	0.50 mm	0.20 mm
Hypotype #74*	0.20 mm	0.38 mm	0.18 mm

Hypotype #75* 0.16 mm 0.42 mm 0.16 mm

Remarks. *H. swareni* was described by Stelck and Hedinger (1976) from the Late Albian Sully Formation in northeastern British Columbia. The present form is similar to *H. swareni* in most respects except that it often has fewer chambers in the uniserial portion and seems to lack the "secondary cribration" characteristic of *H. swareni*. *A. tyrrelli* is also very similar to *H.* cf. *swareni* except that the former species has a planispiral initial coil.

H. cf. *swareni* is distinguished from co-existing species of *Ammobaculites* by its loosely streptospiral coil. *Haplophragmium* sp. from the "Attachie" sequence shows a marked tendency to add successively larger chambers in the uniserial part, thus imparting a flaring appearance to mature specimens.

Haplophragmium sp.

Plate 6, figures 5a,b, 6

Description. Test free, small to medium, elongate, often flaring towards the aperture, consisting of a streptospiral coil of about 5 chambers followed by a uniserial portion of 2-4 chambers, coil is usually the same size or slightly larger in diameter than the first uniserial chamber; chambers inflated, increasing rapidly in size in uniserial part; sutures distinct, depressed, often undulating in

uniserial part, may be thickened; wall finely agglutinated, well constructed with much cement, texture smooth to sucrosic; aperture terminal, rounded, produced on a distinct neck.

Types and occurrence. This form in found in the "Attachie" sequence. Thesis hypotypes are: 61*, 62, 63*, 64.

Dimensions:

	Coil	Length	Breadth
Hypotype #61*	0.18 mm	0.40 mm	0.22 mm
Hypotype #62	0.18 mm	0.72 mm	0.24 mm
Hypotype #63*	0.18 mm	0.36 mm	0.16 mm

Remarks. This form has apparently not been described in the literature. The flaring test and streptospiral coil distinguish it easily from other forms in the suites. The flaring test is very reminiscent of *Ammobaculites fragmentarius*, but the latter species has a planispiral initial coil.

Family TEXTULARIDAE Ehrenberg, 1838

Subfamily PSEUDOBOLIVININAE Weisner, 1931

Genus *Pseudobolivina* Weisner, 1931

Pseudobolivina variana (Eicher), 1960

Plate 6, figure 8; Plate 9, figures 21a,b

1960. *Bimonolina variana* Eicher, p. 67, pl. 4, figs. 15- 19

1963. *Bimonolina variana* Eicher, Crespin, p. 55-56, pl. 14, figs. 15-19

1965. *Pseudobolivina variana* (Eicher), Eicher, p. 897-898, pl. 104, fig. 8

1967. *Pseudobolivina variana* (Eicher), Eicher, p. 183, pl. 18, fig. 1

1967. *Pseudobolivina* sp. 1, Wall, p. 66-67, pl. 4, fig. 24; pl. 11, figs. 17-24

1975. *Pseudobolivina variana* (Eicher), North and Caldwell, pl. 2, figs. 19a,b, 20

1977. *Pseudobolivina variana* (Eicher), McNeil, p. 192-193, pl. 11, fig. 3

Description. Test free, small to medium, elongate, flaring, biserial with a twisted axis; chambers probably originally inflated, usually flattened, increasing rapidly in size; sutures distinct, depressed to constricted; wall finely arenaceous, smooth, usually light grey or amber in color; aperture appears slit-like, terminal on the final chamber.

Types and occurrence. This species is rare in the basal part

of the "Attachie" section and occurs sporadically throughout the "Hasler" sequence. Thesis hypotypes are: M1*, M2*, M3-M6.

Dimensions:

	Length	Breadth
Hypotype #M1*	0.62 mm	0.30 mm
Hypotype #M2*	0.52 mm	0.28 mm
Hypotype #M3	0.38 mm	0.24 mm

Remarks. Eicher (1960) originally described *P. variana* from the Shell Creek, Thermopolis, and Skull Creek Shales (Albian of Wyoming). Eicher subsequently recorded it from the Cenomanian Graneros Shale and Albian Mowry Shale of Wyoming and Colorado (1965) and from the Cenomanian Belle Fourche Shale of Montana and Wyoming (1967). In Canada, it has been described from Cenomanian to Campanian rocks in the Foothills of Alberta (as *Pseudobolivina* sp. 1 of Wall, 1967) and from Albian beds in the Lower Colorado Group and Ashville Formation of Saskatchewan and Manitoba (North and Caldwell, 1975). A similar form, ?*Siphotextularia rayi* Tappan has been reported from Albian-Cenomanian beds in Alaska (Tappan, 1962). The last mentioned form, however, appears to have a less strongly flaring test and a greater average size. *"Tritaxia" athabaskensis* Mellon and Wall, another comparable form, was described from the Clearwater Formation of Alberta (Mellon and Wall, 1956). A figure of *"Tritaxia" athabaskensis* in Stelck et al. (1956, pl.2, figs.

15, 16) appears identical to the present form.

This species resembles <u>Textularia</u> species but the flattened aperture appears large and slit-like and it is often produced on what may have been a short neck. A twisted axis is evident from the curved, irregular nature of the flattened tests. Eicher (1960) described 2 distinct morphotypes for this species. The microspheric form has more chambers, a strongly flaring test, and is less abundant than the megalospheric form. The latter morphotype often has larger chambers and may appear irregularly formed because of the strongly twisted axis. No megalospheric forms were noted in this study. It did, however, occur to the author that large, megalospheric individuals might be difficult to distinguish from distorted specimens of <u>Uvigerinammina manitobensis</u> that lacked necks.

Subfamily PLECTORECURVOIDINAE Loeblich and Tappan, 1964

Genus <u>Plectorecurvoides</u> Noth, 1952

<u>Plectorecurvoides</u> sp.

Plate 6, figure 7a-c

<u>Description</u>. Test free, small to medium, biserial enrolled, almost spherical in overall shape; chambers only slightly or not inflated, numbering about 10-20 visible from the exterior of the test; sutures distinct, apressed to depressed, often imparting crude hexagonal or pentagonal shapes to the chambers; wall finely to medium agglutinated,

neatly constructed but may appear somewhat rough; aperture not characterized, probably interiomarginal.

Types and occurrence. This species is confined to the "Attachie" section from which only one well preserved specimen was recovered. However, another 6 damaged fossils were found that probably belong to this species. Thesis hypotypes are: M7*, M8-M13.

Dimensions:

	Length	Breadth
Hypotype #M7*	0.30 mm	0.28 mm
Hypotype #M9	0.30 mm	0.22 mm
Hypotype #M11	0.20 mm	0.18 mm

Remarks. This genus has been reported from Albian rocks in Austria, Czechoslovakia, and the USSR (see Loeblich and Tappan, 1964).

The present species is easily distinguished from all others in this study by its characteristic globular shape. Crushed specimens, however, are difficult to differentiate from poorly preserved planispiral or trochospiral forms.

Family TROCHAMMINIDAE Schwager, 1877

Subfamily TROCHAMMININAE Schwager, 1877

Genus *Trochammina* Parker and Jones, 1859

Trochammina depressa Lozo, 1944

Plate 7, figures 1-4

1944. *Trochammina depressa* Lozo, p. 552, pl. 2, figs. 4, 5

1949. *Trochammina depressa* Lozo, Loeblich and Tappan, p. 256, pl. 149, figs. 1, 2

1950. *Trochammina callima* Loeblich and Tappan, p. 10, pl. 1, figs. 2, 3; pl. 2, figs. 4, 5

1954. *Trochammina depressa* Lozo, Frizzell, p. 79, pl. 7, figs. 13a,b

1958. *Trochammina depressa* Lozo, Skolnick, p. 284, pl. 38, figs. 3a-c

1960. *Trochammina depressa* Lozo, Eicher, p. 74, pl. 6, figs. 3, 4

1967. *Trochammina depressa* Lozo, Guliov, p. 33-34, pl. 7, figs. 1a-c

1977. *Trochammina depressa* Lozo, McNeil, p. 197-198, pl. 11, figs. 8a-c

Description. Test free, small to medium, trochospiral with about 6 chambers in the final whorl, compressed (probably mostly due to crushing), deeply umbilicate on the ventral side, periphery faintly lobulate or somewhat angular; chambers only slightly inflated in intact specimens, inreasing rather rapidly in size; sutures distinct,

depressed, slightly curved backwards on spiral side, radial and straight on umbilical side (if undistorted); wall finely to medium arenaceous, smooth or rough; aperture an interiomarginal slit that begins at the base of the ultimate chamber and extends towards the umbilicus.

Types and occurrence. This species is found only in the "Attachie" section where it is moderately common. Thesis hypotypes are: N7*-N10*, N11-N13.

Dimensions:

	Diameter	Thickness
Hypotype #N7*	0.42 mm	0.18 mm
Hypotype #N8*	0.44 mm	0.20 mm
Hypotype #N13	0.38 mm	0.08 mm

Remarks. This species was first described from the Albian Kiamichi Shale of Texas (Lozo, 1944). In the United States, it has been reported from the Kiowa Shale of Kansas (as *T. callima* of Loeblich and Tappan, 1950), the Walnut Clay of Texas (Loeblich and Tappan, 1949), the Mowry Shale of Wyoming (Skolnick, 1958), and the Thermopolis and Skull Creek Shales of Wyoming (Eicher, 1960). In addition, it has been identified by Guliov (1967) in the Joli Fou Formation of Saskatchewan. All known occurrences of this species are Albian in age.

Eicher (1960) noted that *T. callima* Loeblich and Tappan

was similar to _T. depressa_ in all respects except thickness--the form from the Kiowa Shale was thicker. Eicher concluded that this was due to varying degrees of burial compression. This opinion is held to be valid as specimens from the "Attachie" section also show these variations in thickness. _T. rainwateri_, another similar form, differs from the present form in its smaller size and greater number of chambers in the final whorl.

Trochammina gatesensis Stelck and Wall, 1956

Plate 6, figures 9a,b, 10a,b

1956. _Trochammina gatesensis_ Stelck and Wall, Stelck, Wall, Bahan, and Martin, p. 53, pl. 4, figs. 9-11

1960, _Trochammina gatesensis_ Stelck and Wall, Eicher, p. 74, pl. 6, figs. 6, 7

1965. _Trochammina gatesensis_ Stelck and Wall, Eicher, p. 878, pl. 105, figs. 2, 3

1967. _Trochammina gatesensis_ Stelck and Wall, Eicher, p. 183, pl. 18, fig. 11

Description. Test free, tiny, trochospiral with about 2 whorls, ultimate whorl having about 7 chambers, peripheral margin slightly lobulate; chambers fairly inflated on uncrushed specimens, increasing gradually in size except for the last 2 or 3 which increase rapidly in size; sutures distinct, depressed, may curve back slightly; wall finely to medium arenaceous, may be somewhat rough; aperture not seen,

assumed interiomarginal at the base of the final chamber.

Types and occurrence. This species is fairly common in the 200 mesh fraction of "Attachie" samples. Thesis hypotypes are: P1*, P2, P3, P4*.

Dimensions:

	Diameter	Thickness
Hypotype #P1*	0.22 mm	0.10 mm
Hypotype #P3	0.24 mm	0.08 mm
Hypotype #P4*	0.20 mm	0.16 mm

Remarks. This species was originally described by Stelck and Wall (Stelck et al., 1956) from the "St. John Shale" of northeastern British Columbia. It has since been recorded from the Albian Shell Creek Shale of Wyoming (Eicher, 1960), the Cenomanian Graneros Shale of Colorado (Eicher, 1965), and the Cenomanian Belle Fourche Shale of Montana and Colorado (Eicher, 1967).

T. alcanensis Stelck differs from the present species in its larger size, thickened sutures, and enlarged final chamber. *T. rutherfordi* has articulated crescent-shaped chambers and a fairly round peripheral margin. The present species resembles *T. diagonis* (Carsey) in some respects, particularly in the characteristic diagonal arrangement of chambers when viewed edge-on. *T. gatesensis*, however, is much smaller. Some specimens assigned to the present species

may represent juvenile individuals of larger forms.

Trochammina sp. cf. *T. rainwateri* Cushman and Applin, 1946

Plate 9, figures 23a,b

Description. Test free, medium to small, very low trochospiral, deeply umbilicate on ventral side, composed of about 3 whorls with about 8 chambers in the final whorl, peripheral margin rounded; chambers not inflated, indistinct to distinct, increasing gradually in size; sutures indistinct, usually straight and radial when visible; wall coarsely agglutinated, grain-size .01-.05mm, rough, amber to reddish brown in color; aperture not characterized, assumed interiomarginal.

Types and occurrence. This form is found in both the "Attachie" and "Hasler" sections. It is moderately common. Thesis hypctypes are: N1*, N2*, N3-N6.

Dimensions:

	Diameter	Thickness
Hypotype #N1*	0.36 mm	0.16 mm
Hypotype #N2*	0.26 mm	0.12 mm
Hypotype #N4	0.40 mm	0.12 mm

Remarks. *T. rainwateri* was first described from the Cenomanian Woodbine Group of Texas (Cushman and Applin, 1946). It has since been reported from many localities in

the Canadian and American western interiors and from Alaska. The stratigraphic range of _T. rainwateri_ appears to be Albian through Turonian (McNeil, 1977).

The present form differs from _T. rainwateri_ chiefly in having a smaller, coarser test. This form somewhat resembles _T. depressa_ Lozo but the latter species is more finely agglutinated and has a slightly lobulate periphery and fewer chambers. The present species is easily identified by its low spire, its deep, wide umbilicus, and its coarse texture.

Trochammina rutherfordi Stelck and Wall, 1955

Plate 2, figures 9a,b, 10a,b; Plate 7, figures 5a,b, 6

1955. _Trochammina rutherfordi_ Stelck and Wall, p. 56-57, pl. 1, figs. 11, 12

1955. _Trochammina rutherfordi_ variety 1 Stelck and Wall, p. 57-58, pl. 1, figs. 14a-c; pl. 3, figs. 20, 21

1955. _Trochammina rutherfordi_ variety 2 Stelck and Wall, p. 58-59, pl. 1, figs. 15, 16; pl. 3, figs. 36, 37

1958. _Trochammina rutherfordi_ variety 2 Stelck and Wall, Stelck, Wall, and Wetter, p. 33-34, pl. 4, figs. 6-10

1962. _Trochammina ribstonensis_ Wickenden subspecies _rutherfordi_ Stelck and Wall, Tappan, p. 155-156, pl. 39, figs. 18-20

1965. _Trochammina rutherfordi_ Stelck and Wall, Eicher, p. 899-900, pl. 105, figs. 1a-c

1967. _Trochammina rutherfordi_ Stelck and Wall, Wall, p. 70-

71, pl. 2, figs. 8-31; pl. 4, figs. 8-13

1971. *Trochammina rutherfordi* Stelck and Wall, Morris, p. 272-273, pl. 4, figs. 2-4

1975. *Trochammina rutherfordi* Stelck and Wall, North and Caldwell, pl. 3, figs. 1a-c

1977. *Trochammina rutherfordi* Stelck and Wall, McNeil, p. 203-205, pl. 12, figs. 2a-c

Description. Test free, small, low trochospiral, with rounded or faintly lobulate periphery, composed of 2-3 whorls with 6-7 chambers in final whorl; chambers distinct, enlarging gradually; sutures distinct, depressed, curved on both sides of the test; wall finely arenaceous, usually smoothed with lots of cement; aperture not characterized, probably interiomarginal.

Types and occurrence. This species is found in the "Attachie" and "Farrel" sections where it is generally uncommon. Thesis hyotypes are: P5*, P6-P8, P9*, P10, P11*, P12*, P13-P16.

Dimensions:

	Diameter	Thickness
Hypotype #P9*	0.22 mm	0.08 mm
Hypotype #P11*	0.28 mm	0.12 mm
Hypotype #P12*	0.26 mm	0.14 mm

Remarks. *T. rutherfordi* was first described from the

Cenomanian-Turonian part of the Kaskapau Formation of Alberta (Stelck and Wall, 1955). Stelck et al. (1956) identified it in the Cenomanian Dunvegan Formation and the Albian-Cenomanian Fort St. John Group of Alberta, and Wall (1967) found it in the Cenomanian-Turonian Sunkay and Haven Members of the Blackstone Formation, also of Alberta. North and Caldwell (1975) figure _T. rutherfordi_ from the Albian upper part of the Lower Colorado Group and Ashville Formation in Saskatchewan and Manitoba. In the United States, Eicher (1965) has recorded it from the Cenomanian Graneros Shale of Colorado and Wyoming, Morris (1971) found it in the Upper Cretaceous Mesaverde Group of Colorado, and Tappan (1962) identified it (as _T. ribstonensis_ Wickenden subspecies _rutherfordi_) in the Albian Grandstand and Cenomanian Ninuluk Formations of Alaska.

This species is distinguished by its small size, low spiral, and articulated crescent-shaped chambers. It was considered a subspecies of _T. ribstonensis_ Wickenden by Tappan (1962) but this opinion is not followed here. _T. ribstonensis_ is larger and has more chambers per whorl.

Trochammina rutherfordi s. sp. cf. *T. rutherfordi mellariolum* Eicher, 1965

Plate 2, figures 12a-c

Description. Test free, small, trochospiral with a high spire, composed of about 3-4 whorls with about 4 chambers in the final whorl, peripheral margin lobulate; chambers inflated, subglobular (in umbilical view) to elongate (in spiral view), rapidly expanding in size (especially over the last whorl); sutures distinct, depressed, wall finely agglutinated, texture glassy to sucrosic; aperture an interiomarginal slit at the base of the ultimate chamber.

Types and occurrence. This form is confined to the "Farrel" section. Only 2 specimens were recovered. Thesis hypotypes are: U7*, U8*.

Dimensions:

	Diameter	Thickness
Hypotype #U7*	0.24 mm	0.20 mm
Hypotype #U8*	0.22 mm	0.30 mm

Remarks. Eicher (1965) described *T. rutherfordi mellariolum* from the Cenomanian Graneros Shale of Colorado. Eicher (1967) subsequently reported this subspecies from the Cenomanian Belle Fourche Shale of Montana. Sutherland and Stelck (1972) found it in the Upper Albian *Neogastroplites* zone of northeastern British Columbia. Although the present

form appears identical to the parent form in all respects, it is not assigned to T. rutherfordi mellariolum in the strict sense because of limited material.

This form is easily distinguished from T. rutherfordi rutherfordi Stelck and Wall by its high to extremely high spire. In fact, specimens with very high thickness to diameter ratios would be difficult to separate from specimens of the genus Eggerella.

Trochammina wetteri Stelck and Wall, 1955

Plate 2, figures 11a,b, 13a,b

1955. Trochammina wetteri Stelck and Wall, p. 59-60, pl. 2, figs. 1-3, 6

1960. Trochammina wetteri Stelck and Wall, Wall, p. 27, pl. 5, figs. 1-6

1962. Trochammina ribstonensis Wickenden, Tappan, p. 154, pl. 39, fig. 15a-c

1967. Trochammina wetteri Stelck and Wall, Eicher, p. 184-185, pl. 18, figs. 7a,b, 9a-c

1967. Trochammina wetteri Stelck and Wall, Wall, p. 71-72, pl. 8, figs. 21-26; pl. 10, figs. 7-9

1970. Trochammina wetteri Stelck and Wall, Eicher and Worstell, p. 282, pl. 1, fig. 16a-c

1972. Trochammina wetteri Stelck and Wall, Sutherland and Stelck, p. 575-576, pl. 5, figs. 5, 6

1977. Trochammina wetteri Stelck and Wall, McNeil, p. 205-

207, pl. 11, figs. 10a-c

Description. Test free, small to medium, trochospiral with 2-3 whorls, periphery lobulate; chambers inflated, few in number, increasing rapidly in size, numbering 4 to 6 in the ultimate whorl; sutures distinct, depressed to constricted, oblique in spiral view, almost radial in umbilical view; wall finely to medium agglutinated, usually smoothly finished; aperture an interiomarginal slit at the base of the final chamber.

Types and occurrence. This species is present in both the "Farrel" and "Attachie" sections. It is scarcest in the "Hasler" section where only 2 specimens were positively identified. Thesis hypotypes are: Q1, Q2, Q3*, Q4*, Q5-Q10.

Dimensions:

	Diameter	Thickness
Hypotype #Q3*	0.32 mm	0.10 mm
Hypotype #Q6	0.44 mm	0.12 mm
Hypotype #Q7	0.38 mm	0.16 mm

Remarks. This species was first described by Stelck and Wall (1955) from the Cenomanian-Turonian Kaskapau Formation of Alberta. It has since been recorded from the Santonian-Campanian Puskwaskau Formation of Alberta (Wall, 1960), the Turonian-Campanian Seabee and Schrader Bluff Formations of Alaska (as *T. ribstonensis* of Tappan, 1962), the Cenomanian

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Belle Fourche Shale of Colorado, Montana, and Wyoming (Eicher, 1967), the Cenomanian-Turonian Greenhorn Limestone of Wyoming and South Dakota (Eicher and Worstell, 1970), and the *Neogastroplites* zone near Moberly Lake in northeastern British Columbia (Sutherland and Stelck, 1972).

Eicher (1967) and McNeil (1977) regard *T. umiatensis* Tappan (1957) as being synonymous with *T. wetteri*. This view is not held here, however, as *T. wetteri* is small and has 4-6 chambers in the outer whorl while *T. umiatensis* is much larger and has 4 (rarely 5) chambers in each whorl. The larger Alaskan form seems to be restricted to Albian rocks (Tappan, 1962; Sutherland and Stelck, 1972; Stelck, 1975) whereas the smaller *T. wetteri* is found in rocks from Albian to Campanian in age. There exists the possibility that some older (Albian) examples of *T. wetteri* may be conspecific with co-existing specimens of *T. umiatensis* , but the smaller Upper Cretaceous forms are distinct, perhaps descendents of *T. umiatensis*.

Trochammina sp. cf. *T. wickendeni* Loeblich, 1946

Plate 9, figures 25a,b

Description. Test free, small, robust, trochospiral with 1-2 whorls of chambers, about 5 chambers in the final whorl, peripheral margin lobulate; chambers inflated, increasing rapidly in size; sutures distinct, depressed, straight or gently curving; wall finely agglutinated, smooth to almost

glassy; aperture not seen, assumed interiomarginal.

Types and occurrence. This form is very rare in the "Hasler" section. Only 2 specimens were recovered. Thesis hypotypes are: Q11*, Q12.

Dimensions:

	Diameter	Thickness
Hypotype #Q11*	0.36 mm	0.18 mm
Hypotype #Q12	0.36 mm	0.14 mm

Remarks. T. wickendeni was first described from the Cenomanian Pepper Shale of Texas (Loeblich, 1946). It has since been recorded from the Cenomanian Belle Fourche and Carlile Shales of Wyoming and South Dakota (Fox, 1954), the Cenomanian Carlile Shale of Colorado (Eicher, 1966), and the Neogastroplites zone in northeastern British Columbia (Sutherland and Stelck, 1972). Thus, the principal development appears to occur in the Cenomanian.

T. cf. wickendeni is easy to recognize by its somewhat disorganized whorls of rapidly expanding chambers. The total number of chambers seldom exceeds 10. The present form has not been assigned to T. wickendeni sensu stricto because not enough material was available to characterize its variation. The possibility exists that the present form could represent the megalospheric phase of T. wetteri.

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Family ATAXOPHRAGMIIDAE Schwager, 1877

Subfamily VERNEUILININAE Cushman, 1911

Genus *Verneuilina* d'Orbigny, 1839

Verneuilina canadensis Cushman, 1927

Plate 7, figure 7; Plate 9, figure 22

1927. *Verneuilina canadensis* Cushman, p. 131, pl. 1, fig. 11

1937. *Verneuilina canadensis* Cushman, Cushman, p. 13, pl. 1, figs. 16, 17

1946. *Verneuilina canadensis* Cushman, Cushman, p. 12, pl. 7, figs. 2, 3

1960. *Verneuilina canadensis* Cushman, Eicher, p. 67-68, pl. 5, figs. 1, 2

1965. *Verneuilina canadensis* Cushman, Eicher, p. 901, pl. 105, fig. 5

1967. *Verneuilina canadensis* Cushman, Wall, p. 74-75, pl. 1, figs. 14, 15

1975. *Verneuilina canadensis* Cushman, North and Caldwell, pl. 3, figs. 6a,b

1977. *Verneuilina canadensis* Cushman, McNeil, p. 207-208, pl. 12, fig. 3

Description. Test free, flaring, medium to large, triserial with each row of chambers registering perfectly on the previous row; chambers inflated, may be secondarily crushed or distorted; sutures distinct, depressed, or constricted; wall very coarsely arenaceous, grain-size .01-.10mm, rough, deep amber in color; aperture not determined, probably

interiomarginal.

Types and occurrence. This species is rare in the sampled sections. The "Hasler" and "Attachie" sequences yielded only 2 specimens each. Thesis hypotypes are: R1*, R2, R3*, R4.

Dimensions:

	Length	Breadth
Hypotype #R1*	0.88 mm	0.40 mm
Hypotype #R2	0.58 mm	0.32 mm
Hypotype #R3*	0.48 mm	0.32 mm

Remarks. This species was first described by Cushman (1927, 1937, 1946) from Cretaceous rocks of Western Canada. Eicher recorded it from the Cenomanian Graneros Shale of Colorado (1965) and the Albian Skull Creek Shale of Wyoming (1960). Wall (1967) reported it from the Sunkay Member of the Albian Blackstone Formation of Alberta and the Albian part of the Shaftesbury Formation in the Peace River area, Alberta. North and Caldwell (1975) recovered this species from the Albian Lower Colcrado Group and Ashville Formation in Saskatchewan and Manitoba.

This large Verneuilina is easily recognized by its coarse texture and highly inflated chambers. It resembles Verneuilinoides sp. except that the chambers are lined up in vertical rows separated by deep clefts.

Genus Gaudryina d'Orbigny, 1839

Gaudryina canadensis Cushman, 1943

Plate 7, figures 8-10

1927. Bigenerina angulata Cushman, p. 131, pl. 1, fig. 10

1943. Gaudryina canadensis Cushman, p. 28, pl. 6, figs. 7, 8

1946. Gaudryina canadensis Cushman, Cushman, p. 34, pl. 6, fig. 24

1947. Gaudryina hectori Nauss, p. 335, pl. 48, figs. 6a,b

1956. Gaudryina hectori Nauss, Stelck, Wall, Bahan, and Martin, p. 32, pl. 5, figs. 14, 15

1960. Verneuilinoides hectori (Nauss), Eicher, p. 68, pl. figs. 3, 4

1962. Gaudryina canadensis Cushman, Tappan, p. 146, pl. 35, figs. 1-7

1965. Verneuilinoides hectori (Nauss), Eicher, p. 901, pl. 105, figs. 6, 7

1967. Gaudryina hectori Nauss, Guliov, p. 34-35, pl. 7, figs. 2a,b

1972. Verneuilinoides hectori (Nauss), Morris, p. 273-274, pl. 4, figs. 8-11

1975. Gaudryina canadensis Cushman, North and Caldwell, pl. 3, figs. 9a,b, 10a,b, 11a,b

1977. Gaudryina canadensis Cushman, McNeil, p. 210-213, pl. 12, figs. 10, 11

Description. Test free, medium to large, elongate, initial portion triserial, later becoming biserial, usually with a

slightly twisted axis of coiling in the biserial portion; chambers only slightly inflated, increasing gradually in size; sutures distinct, often somewhat thickened, usually straight, giving a zig-zag appearance to the test; wall medium arenaceous, finished with lots of cement, color amber to reddish-brown; aperture a high arch extending well onto the face of the final chamber from an interiomarginal position.

Types and occurrence. This species is present only in the "Attachie" section where it is included in the *Haplophragmoides gigas* fauna. Thesis hypotypes are: R5*, R6*, R7-R9, R10*, R11-R13.

Dimensions:

	Length	Breadth
Hypotype #R5*	0.70 mm	0.20 mm
Hypotype #R6*	0.64 mm	0.24 mm
Hypotype #R10*	0.46 mm	0.20 mm

Remarks. This species was originally described as *Bigenerina angulata* from poorly preserved material from the Cretaceous of western Canada (Cushman, 1927, 1943, 1946). As *G. hectori* this species has been recorded from Albian beds in the Lloydminster Shale (Nauss, 1947), and the Albian Joli Fou Formation of Alberta (Stelck et al., 1956) and Saskatchewan (Guliov, 1967). As *Verneuilinoides hectori* (Nauss), Eicher identified the present species in the Albian Thermopolis,

Skull Creek, Shell Creek, and Mowry Shales of Wyoming (1960) and the Albian upper Mowry and Cenomanian Graneros Shales of Colorado (1965). Morris (1971) found it in the Upper Cretaceous Mesaverde Group of Colorado and Tappan (1962) recorded it from Albian-Cenomanian rocks in Alaska. North and Caldwell (1975) figured specimens from the Lower Colorado Group and Ashville Formation in Saskatchewan and Manitoba.

Juveniles of the present species are often confused with specimens of Verneuilinoides, which they strongly resemble. The mature form, however, is easily identified by its zig-zag sutures and commonly twisted axis. G. irenensis Stelck and Wall, a similar species, is distinguished from the present one by its stouter and relatively longer triserial portion (Stelck and Wall, 1955).

Genus Uvigerinammina Majzon, 1943

Uvigerinammina manitobensis (Wickenden), 1932

Plate 7, figures 11-13; Plate 9, figures 24, 26-28

1932. Tritaxia manitobensis Wickenden, p. 87-88, pl. 1, fig. 10

1937. Tritaxia manitobensis Wickenden, Cushman, p. 27, pl. 4, fig. 7

1946. Tritaxia manitobensis Wickenden, Cushman, p. 31, pl. 7, fig. 8

1951. Tritaxia manitobensis Wickenden, Tappan, p. 3, pl. 1,

figs. 15, 17

1962. Uvigerinammina manitobensis (Wickenden), Tappan, p. 145, pl. 33, figs. 18-23

1964. Uvigerinammina manitobensis (Wickenden), Loeblich and Tappan, p. C272, figs. 182 (12a,b, 13)

1967. Uvigerinammina cf. manitobensis (Wickenden), Guliov, p. 35-36, pl. 7, fig. 3

1975. "Tritaxia" manitobensis Wickenden, Stelck, pl. 3, fig. 24

1975. Uvigerinammina manitobensis (Wickenden), North and Caldwell, pl. 3, figs. 18a,b

1977. Uvigerinammina manitobensis (Wickenden), McNeil, p. 217-218, pl. 12, figs. 15- 18

Description. Test free, medium, elongate, composed of an initial triserial portion followed by a twisted biserial (sometimes tending to uniserial) portion; chambers originally inflated, usually flattened, sometimes egg-shaped; sutures distinct, depressed to constricted; wall finely agglutinated, smooth, often a characteristic whitish-grey; aperture rounded, terminal, produced on a prominent neck.

Types and occurrence. This species occurs in both the "Attachie" and "Hasler" sections. Only about 2 dozen examples were found. Thesis hypotypes are: S1*, S2*, S3-S6, S7*, S8, S9*, S10*, S11, S12, S13*, S14*, S15-S18.

Dimensions:

	Length	Breadth
Hypotype #S1*	0.62 mm	0.30 mm
Hypotype #S9*	0.46 mm	0.24 mm
Hypotype #S14*	0.72 mm	0.30 mm

Remarks. This species was first described from the Albian-Cenomanian Ashville Formation of Manitoba (Wickenden, 1932). In Canada it has been reported from the Albian Joli Fou Formation of Saskatchewan (Guliov, 1967), Albian beds of the Lower Colorado Group and Ashville Formation in Saskatchewan and Manitoba (North and Caldwell, 1975), Albian beds of the Buckinghorse and Sikanni Formations of northeastern British Columbia (Stelck, 1975), and the Albian Neogastroplites zone in northeastern British Columbia (Sutherland and Stelck, 1972). In addition, Tappan (1962) identified it in Albian rocks of Alaska.

This species was originally described as Tritaxia manitobensis Wickenden. Tappan (1962) noted that the test was trochoid rather than strictly triserial and that it had a rounded rather than a triangular test. On the basis of these observations, she placed it in Uvigerinammina Majzon. Although satisfactory for the Alaskan forms and eastern European varieties, this generic assignment is not strictly applicable to the western Canadian form. The early portion of the present species is very much like that of Uvigerinammina s. s. but the tendency of the Canadian form

to become biserial or even semi-uniserial cannot be ignored. Also, because of deformation due to the original plastic nature of the present form, there is some doubt as to whether its internal structure is the same as that of true Uvigerinammina (which has a series of internal stolon-like necks connecting successive sac-like chambers).

Large specimens of Pseudobolivina variána Eicher may resemble crushed specimens of the present species. Usually, P. variana is more slender and has a more pointed taper towards the proloculus.

Genus Verneuilinoides Loeblich and Tappan, 1949

Verneuilinoides cummingensis (Nauss), 1947

Plate 2, figure 14

1947. "Verneuilina" cummingensis Nauss, p. 341, pl. 49, fig. 4

1975. Verneuilinoides cummingensis (Nauss), North and Caldwell, pl. 3, figs. 4, 5a,b

Description. Test free, small to medium, elongate, triserial with a straight or very slightly twisted axis; chambers medium inflated, subglobular; sutures distinct, depressed; wall finely agglutinated, fairly smooth; aperture an arched slit at the base of the terminal chamber.

Types and occurrence. This species is found in the "Farrel"

section. Only a few specimens were recovered. Thesis hypotypes are: T8*, T9.

Dimensions:

	Length	Breadth
Hypotype #T8*	0.42 mm	0.22 mm
Hypotype #T9	0.44 mm	0.26 mm

Remarks. This species was described from the Cummings Member of the Mannville Formation of Alberta (Nauss, 1947). North and Caldwell (1975) figured it from the Albian-Cenomanian parts of the Lower Colorado Group and Ashville Formation in Saskatchewan and Manitoba.

This species is distinguished from *V. kansasensis* Loeblich and Tappan by its larger size. *V. borealis* Tappan has a more twisted axis.

Subfamily GLOBOTEXTULARIINAE Cushman, 1927

Genus *Arenobulimina* Cushman, 1927

Arenobulimina paynei Tappan, 1957

Plate 2, figures 15a-c, 16; Plate 7, figures 14, 15a,b

1956. *Eggerella* sp. B Stelck, Wall, Bahan, and Martin, p. 31-32, pl. 4, fig. 7

1957. *Arenobulimina paynei* Tappan, p. 208, pl. 67, figs. 1-4

1960. *Eggerella* sp. Eicher, p. 70, pl. 5, fig. 5

1962. *Arenobulimina paynei* Tappan, Tappan, p. 151-152, pl.

36, figs. 1-4

1975. Arenobulimina paynei Tappan, North and Caldwell, pl. 3, figs. 16, 17

Description. Test free, small to medium, strongly flaring, inflated, loosely to strictly quadriserial, late whorls always neatly quadriserial, about 4-5 whorls total; chambers inflated, increasing rapidly in size; sutures distinct, depressed to constricted; wall finely agglutinated, smooth; aperture interiomarginal at the inner margin of the ultimate chamber.

Types and occurrence. This species occurs in the "Attachie" and "Halfway Harmon" sections. It is very rare. Thesis hypotypes are: U1*, U2*, U3-U5, U6*.

Dimensions:

	Length	Breadth
Hypotype #U1*	0.44 mm	0.26 mm
Hypotype #U2*	0.34 mm	0.24 mm
Hypotype #U6*	0.26 mm	0.32 mm

Remarks. This species has been reported from the Albian Grandstand and Topagoruk Formations of the North Slope of Alaska (Tappan, 1957, 1962). North and Caldwell (1975) figure this form from the Lower Colorado Group and Ashville Formation in Sakatchewan and Manitoba. It was reported by Stelck et al. (1956) from the middle Albian Commotion

Formation of northeastern British Columbia (as *Eggerella* sp. B). Eicher (1960) described this species as *Eggerella* sp. from the Shell Creek Shale of Wyoming.

This species is easy to identify by its extremely flaring test and final quadriserial condition. *Gravellina chamneyi* Stelck has a more gradually flaring test and is smaller.

Genus *Gravellina* Bronnimann, 1933

Gravellina chamneyi Stelck, 1975

Plate 9, figures 29a,b

1975. *Gravellina chamneyi* Stelck, p. 267-268, pl. 3, figs. 27, 28, 37-44

1977. *Gravellina chamneyi* Stelck, McNeil, p. 225-226, pl. 12, figs. 22a,b

Description. Test free, tiny to small, gently flaring, quadriserial (or perhaps triserial?) initially, later whorls definitely quadriserial, axis of coiling usually straight; chambers medium inflated, those of the last whorl may be more inflated; sutures distinct, depressed, gently curved, sometimes giving a polygonal appearance to the chambers; wall finely arenaceous, smooth; aperture an interiomarginal notch at the base of the final chamber.

Types and occurrence. This species is rare in the "Hasler"

section. Thesis hypotypes are: W10*, W11.

Dimensions:

	Length	Breadth
Hypotype #W10*	0.34 mm	0.22 mm
Hypotype #W11	0.24 mm	0.18 mm

Remarks. This tiny quadriserial form has been known in Canada for many years. It was first described by Stelck (1975) in the Albian upper Buckinghorse Shale of northeastern British Columbia. Wall (see Stelck, 1975) considers this species to be a widespread component of post Viking microfaunas in Alberta.

G. chamneyi is distinguished from *Arenobulimina paynei* by its smaller size and more gradually flaring test. *G. chamneyi* shows its greatest concentration in the finest screenings whereas *A. paynei* is found in the coarser residues.

Gravellina sp. cf. *G. chamneyi* Stelck, 1975

Plate 7, figures 16, 17

Description. Test free, tiny to small, flaring towards aperture, appearing quadriserial throughout, peripheral margin of later whorls lobulate, axis of coiling may be straight or slightly twisted; chambers usually inflated, often appearing polygonal; sutures distinct, depressed; wall

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

finely arenaceous, usually smooth; aperture not characterized, probably interiomarginal.

Types and occurrence. This form is found only in the "Attachie" section where it is fairly common. Thesis hypotypes are: W1*, W2-W4, W5*, W6-W9.

Dimensions:

	Length	Breadth
Hypotype #W1*	0.26 mm	0.16 mm
Hypotype #W5*	0.26 mm	0.16 mm
Hypotype #W9	0.30 mm	0.16 mm

Remarks. This form is almost identical to G. chamneyi Stelck from the Albian upper Buckinghorse Formation of northeastern British Columbia (Stelck, 1975). The forms found in the "Attachie" section are herein separated from G. chamneyi sensu stricto because there appears to be a continuous range between G. cf. chamneyi and Gravellina sp. Thus it is not known whether the present form is distinct, or whether it represents a juvenile stage of Gravellina sp.

Gravellina sp.

Plate 7, figures 18a,b, 19

Description. Test free, small to medium, flaring gently, most of test appears quadriserial, last whorl definitely triserial, axis of coiling slightly twisted, especially in

triserial whorl(s), peripheral margin lobulate; chambers inflated, increasing gradually in size; sutures distinct, depressed; wall finely arenaceous, texture usually finely sucrosic, often orange in color; aperture an interiomarginal arch at the base of the final chamber.

Types and occurrence. This species is found only in the "Attachie" section. Thesis hypotypes are: T1*, T2-T4, T5*, T6, T7.

Dimensions:

	Length	Breadth
Hypotype #T1*	0.46 mm	0.22 mm
Hypotype #T5*	0.36 mm	0.18 mm
Hypotype #T6	0.36 mm	0.18 mm

Remarks. This form appears to be related to both *G. chamneyi* and *Verneuilinoides cummingensis* Nauss. The early portion is definitely a well-ordered quadriserial arrangement, but the final whorl is always triserial in mature specimens. In addition, the present form is generally a little larger then *G. chamneyi*. *V. cummingensis* (a form found in the stratigraphically lower "Farrel" section) is triserial throughout and usually larger than the present form.

It is interesting to speculate that *Gravellina* sp. might be intermediate between *G. chamneyi* and a form similar to *V. cummingensis*. Unfortunately, there seems to be no way

of deciding whether immature individuals of the present form belong in G. chamneyi or the present species. In view of this, juveniles of the present form (Along with any specimens of G. chamneyi that might be present) are referred to a separate taxon (see G. cf. chamneyi in this report).

ILLUSTRATIONS OF FORAMINIFERA

See Appendix C for thesis hypotype
numbers cross-referenced with
sample numbers

EXPLANATION OF PLATE 1

Foraminifera from the "Farrel" Section

Magnification about 60X

Figures	
1, 2	*Hippocrepina* sp. A. Hypotypes #B1 (fig. 1) and #B3 (fig. 2).
3-5	?*Hyperammina* sp. alpha. Hypotypes #E2 (fig. 3), #D9 (fig. 4), and #E3 (fig. 5).
6-8, 11-13	*Psamminosphaera* sp. Hypotypes #G4 (fig. 6), #E5 (fig. 7), #G3 (fig. 8), #F6 (fig. 11), #F4 (fig. 12), and #F5 (fig. 13).
9, 10	*Saccammina alexanderi* Loeblich and Tappan. Hypotypes #B2 (fig. 9) and #B4 (fig. 10).
15-18	*Thuramminoides* cf. *septagonalis* Chamney. Hypotypes #I18 (fig. 15), #I17 (fig. 16), #I22 (fig. 17), and #I23 (fig. 18).
14a,b	*Ammodiscus kiowensis* Loeblich and Tappan. Hypotype #J4 (figs. 14a,b).
19, 20	?*Ammodiscus* sp. Hypotypes #J9 (fig. 19) and #J8 (fig. 20).
21, 22	*Psamminopelta bowsheri* Tappan. Hypotypes #J63 (fig. 21) and #J60 (fig. 22).
23a,b	*Haplophragmoides* sp. Hypotype #L21 (figs. 23a,b).
24-28	*Haplophragmoides* cf. *gilberti* Eicher. Hypotypes #L54 (figs. 24a,b), #L47 (figs.

25a,b), #L55 (fig. 26), #L48 (figs. 27a,b), and #L46 (figs. 28a,b).

29a,b *Haplophragmoides* cf. *kirki* Wickenden. Hypotype #L26 (figs. 29a,b).

PLATE 1

"FARREL"

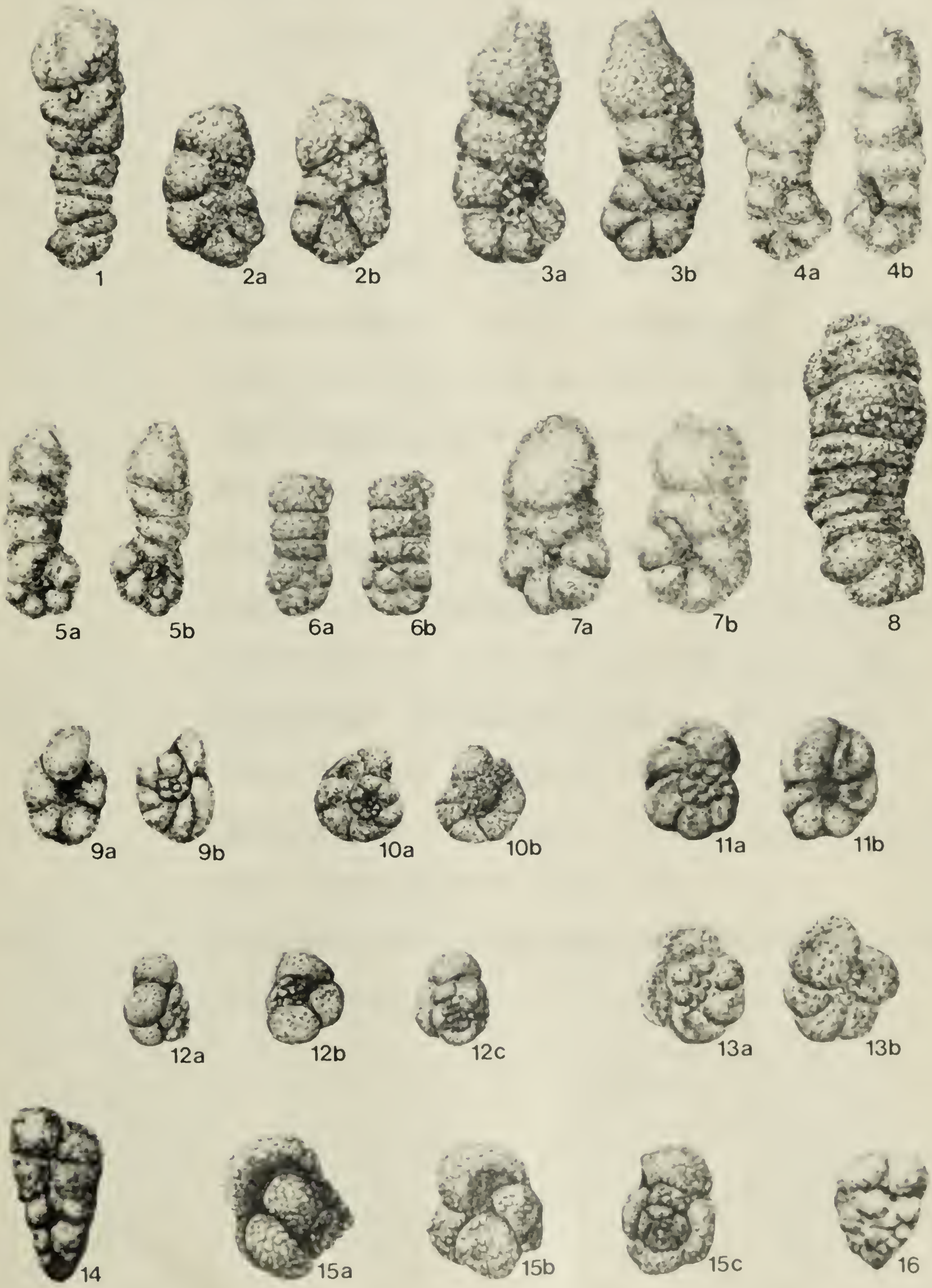
EXPLANATION OF PLATE 2

Foraminifera from the "Farrel" Section

Magnification about 60X

Figures	
1	_Ammobaculites_ _fragmentarius_ Cushman. Hypotype #36.
2-4	_Ammobaculites_ cf. _humei_ Nauss. Hypotypes #11 (figs. 2a,b), #21 (figs. 3a,b), and #20 (figs. 4a,b).
5a,b, 6a,b	_Ammobaculites_ _tyrrelli_ Nauss. Hypotypes #26 (figs. 5a,b) and #77 (figs. 6a,b).
7a,b, 8	_Ammobaculites_ _wenonahae_ Tappan. Hypotypes #47 (figs. 7a,b) and #16 (fig. 8).
9a,b, 10a,b	_Trochammina_ _rutherfordi_ Stelck and Wall. Hypotypes #P11 (figs. 9a,b) and #P12 (figs. 10a,b).
12a-c	_Trochammina_ _rutherfordi_ s. sp. cf. _T._ _rutherfordi_ _mellariolum_ Eicher. Hypotype #U7 (figs. 12a-c).
11a,b, 13a,b	_Trochammina_ _wetteri_ Stelck and Wall. Hypotypes #Q4 (figs. 11a,b) and #Q3 (figs. 13a,b).
14	_Verneuilinoides_ _cummingensis_ Nauss. Hypotype #T8.
15a-c, 16	_Arenobulimina_ _paynei_ Tappan. Hypotypes #U6 (figs. 15a-c) and#U8 (fig. 16).

PLATE 2



"FARREL"

EXPLANATION OF PLATE 3

Foraminifera from the "Attachie" Section

Magnification about 85X

Figures	
1-3	Bathysiphon brosgei Tappan. Hypotypes #A1 (fig. 1), #A3 (fig. 2), and #A2 (fig. 3).
4, 5	Hippocrepina cf. barksdalei (Tappan). Hypotypes #B9 (fig. 4) and #C1 (fig. 5).
6, 8	?Hyperammina alpha. Hypotypes #D7 (fig. 6) and #D5 (fig. 8).
7	Psammosphaera sp. Hypotype #E9.
9, 10	Saccammina alexanderi (Loeblich and Tappan). Hypotypes #H8 (fig. 9) and #H5 (fig. 10).
11, 12	Saccammina lathrami Tappan. Hypotypes #I3 (fig. 11) and #I1 (fig. 12).
13, 14	Reophax cf. eckernex Vieaux. Hypotypes #J16 (fig. 13) and #J17 (fig. 14).
15a,b	Miliammina cf. awunensis Tappan. Hypotype #J48 (figs. 15a,b).

PLATE 3

"ATTACHIE"

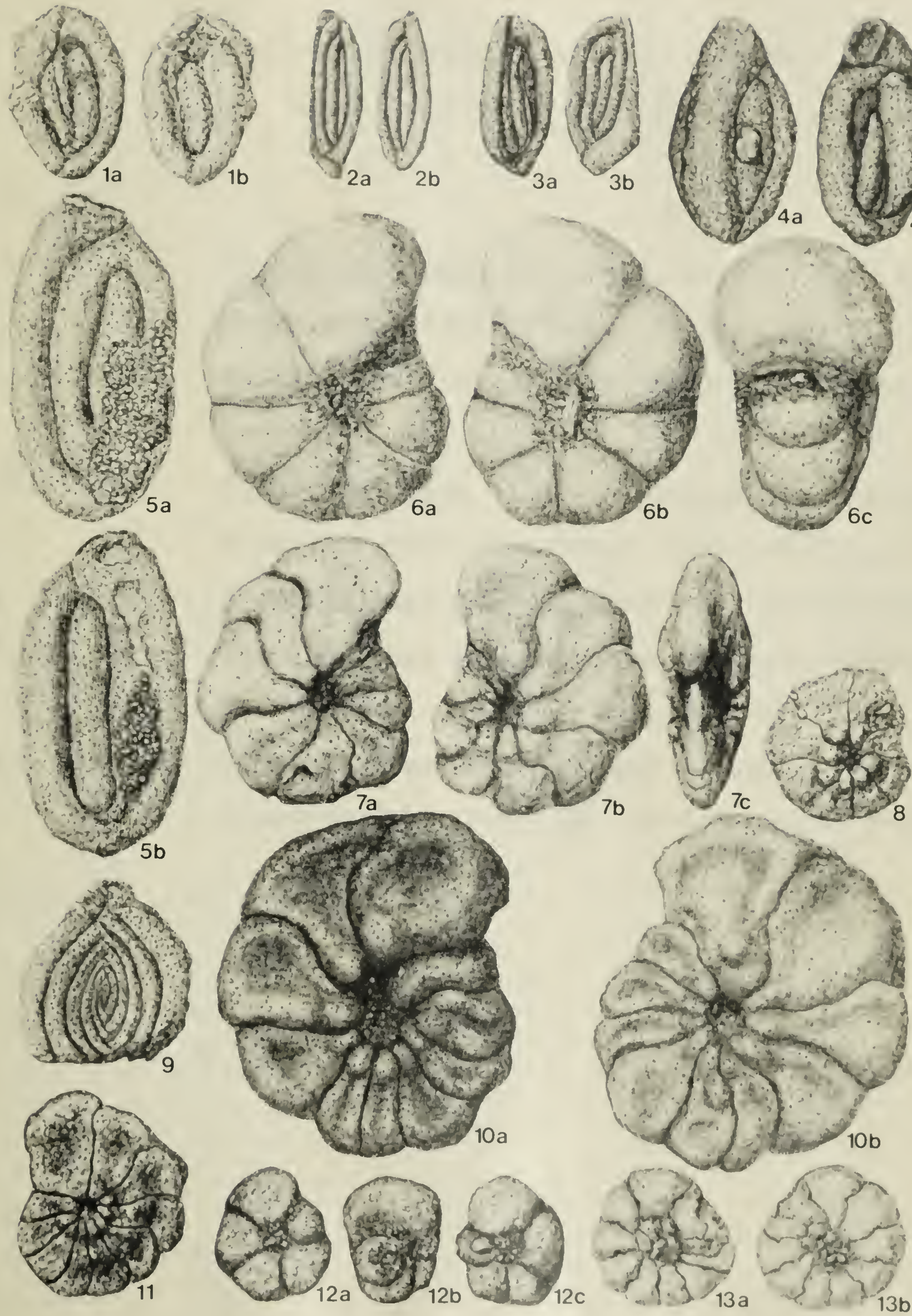
EXPLANATICN OF PLATE 4

Foraminifera from the "Attachie" Section

Magnification about 85X

Figures	
1a,b	*Miliammina inflata* Eicher. Hypotype #J20 (figs. 1a,b).
2a,b, 3a,b	*Miliammina ischnia* Tappan. Hypotypes #J25 (figs. 2a,b) and #J29 (figs. 3a,b).
4a,b, 5a,b	*Miliammina manitobensis* Wickenden. Hypotypes #J51 (figs. 4a,b) and #J50 (figs. 5a,b).
9	*Psamminopelta bowsheri* Tappan. Hypotype #J53.
6a-c	*Haplophragmoides collyra* Nauss. Hypotype #L1 (figs. 6a-c).
7, 8, 10, 11	*Haplophragmoides gigas* Cushman. Hypotypes #L6 (figs. 7a-c), #L8 (fig. 8), #L5 (figs. 10a,b), and #L9 (fig. 11).
12a-c	*Haplophragmoides* cf. *kirki* Wickenden. Hypotype #L16 (figs. 12a-c).
13a,b	*Haplophragmoides* cf. *postis* Stelck and Wall. Hypotype #L36 (figs. 13a,b).

PLATE 4



"ATTACHIE"

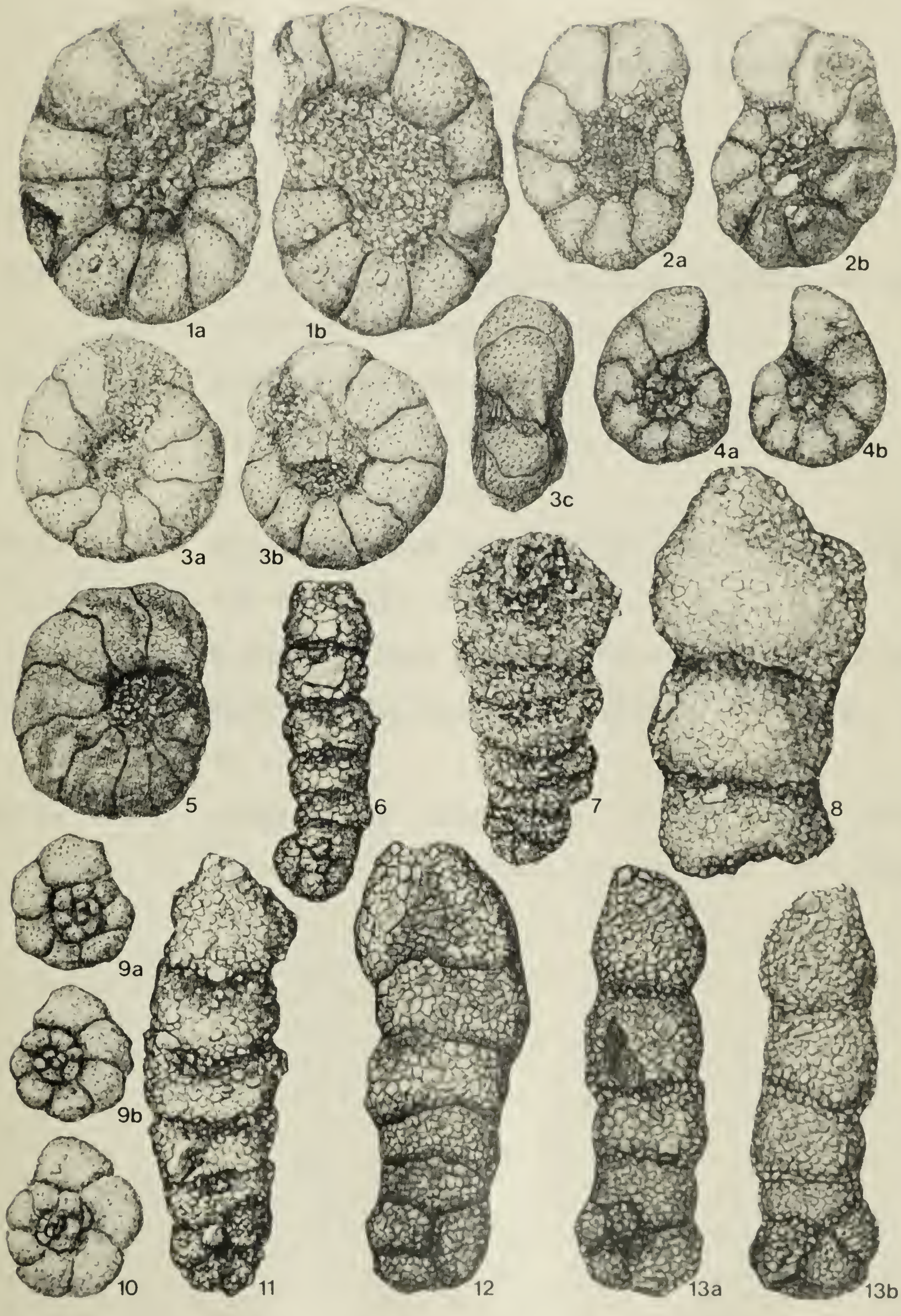
EXPLANATION OF PLATE 5

Foraminifera from the "Attachie" Section

Magnification about 85X

Figures	
1-5	<u>Haplophragmoides</u> cf. <u>postis</u> Stelck and Wall. Hypotypes #K23 (figs. 1a,b), #K27 (figs. 2a,b), #K25 (figs. 3a-c), #K28 (figs. 4a,b), and #K24 (fig. 5).
9a,b, 10	<u>Trochamminoides</u> cf. <u>apricarius</u> Eicher. Hypotypes #L43 (fig. 9a,b) and #L41 (fig. 10).
6	<u>Ammobaculites</u> <u>culmula</u> Skolnick. Hypotype #40.
7, 8, 11	<u>Ammobaculites</u> <u>fragmentarius</u> Cushman. Hypotypes #25 (fig. 7), #42 (fig. 8), and #26 (fig. 11).
12, 13a,b	<u>Ammobaculites</u> <u>fragmentarius</u> Cushman variety. Hypotypes #57 (fig. 12) and #69 (figs. 13a,b).

PLATE 5



"ATTACHIE"

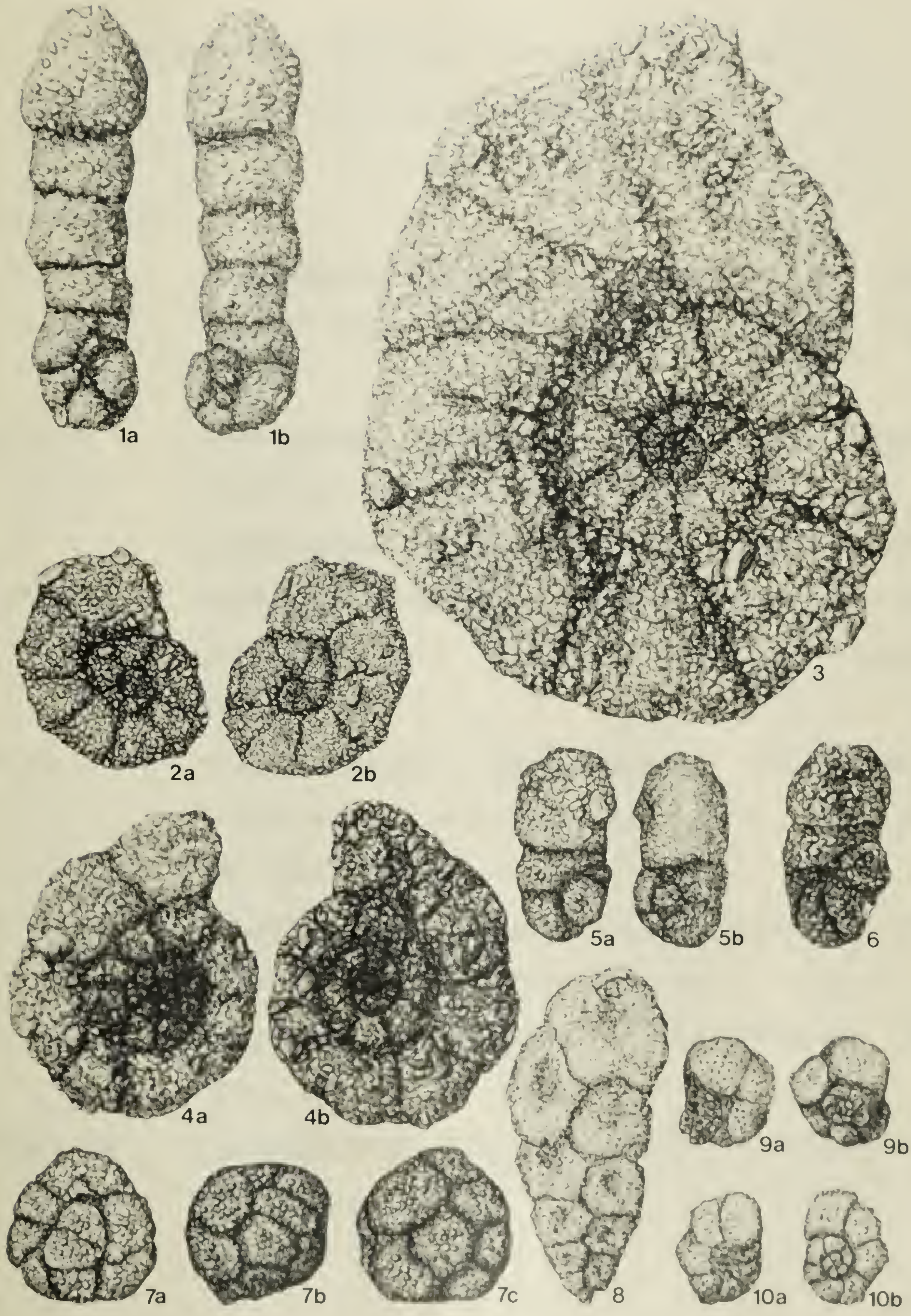
EXPLANATION OF PLATE 6

Foraminifera from the "Attachie" Section

Magnification about 85X

Figures	
1a,b	Ammobaculites fragmentarius Cushman variety. Hypotype #56 (figs. 1a,b).
2-4	Ammomarginulina cragini Loeblich and Tappan. Hypotypes #53 (figs. 2a,b), #51 (fig. 3), and #52 (figs. 4a,b).
5a,b, 6	Haplophragmium sp. Hypotypes #63 (figs. 5a,b) and #61 (fig. 6).
8	Pseudobolivina variana (Eicher). Hypotype #M1.
7a-c	Plectorecurvoides sp. Hypotype #M7 (figs. 7a-c).
9a,b, 10a,b	Trochammina gatesensis Stelck and Wall. Hypotypes #P4 (figs. 9a,b) and #P1 (figs. 10a,b).

PLATE 6



"ATTACHIE"

EXPLANATION OF PLATE 7

Foraminifera from the "Attachie" Section

Magnification about 85X

Figures	
1-4	_Trochammina depressa_ Lozo. Hypotypes #N9 (fig. 1), #N8 (fig. 2), #N10 (fig. 3), and #N7 (fig. 4).
5a,b, 6	_Trochammina rutherfordi_ Stelck and Wall. Hypotypes #P9 (fig. 5a,b) and #P5 (fig. 6).
7	_Verneuilina canadensis_ Cushman. Hypotype #R1.
8-10	_Gaudryina canadensis_ Cushman. Hypotypes #R5 (fig. 8), #R6 (fig. 9), and #R10 (figs. 10a,b).
11-13	_Uvigerinammina manitobensis_ (Wickenden). Hypotypes #S1 (fig. 11), #S2 (fig. 12), and #S7 (figs. 13a,b).
14, 15a,b	_Arenobulimina paynei_ Tappan. Hypotypes #U2 (fig. 14) and #U1 (figs. 15a,b).
16, 17	_Gravellina_ cf. _chamneyi_ Stelck. Hypotypes #W1 (fig. 16) and #W5 (fig. 17).
18a,b, 19	_Gravellina_ sp. Hypotypes #T5 (figs. 18a,b) and #T1 (fig. 19).

PLATE 7

"ATTACHIE"

EXPLANATION OF PLATE 8

Foraminifera from the "Hasler" Section

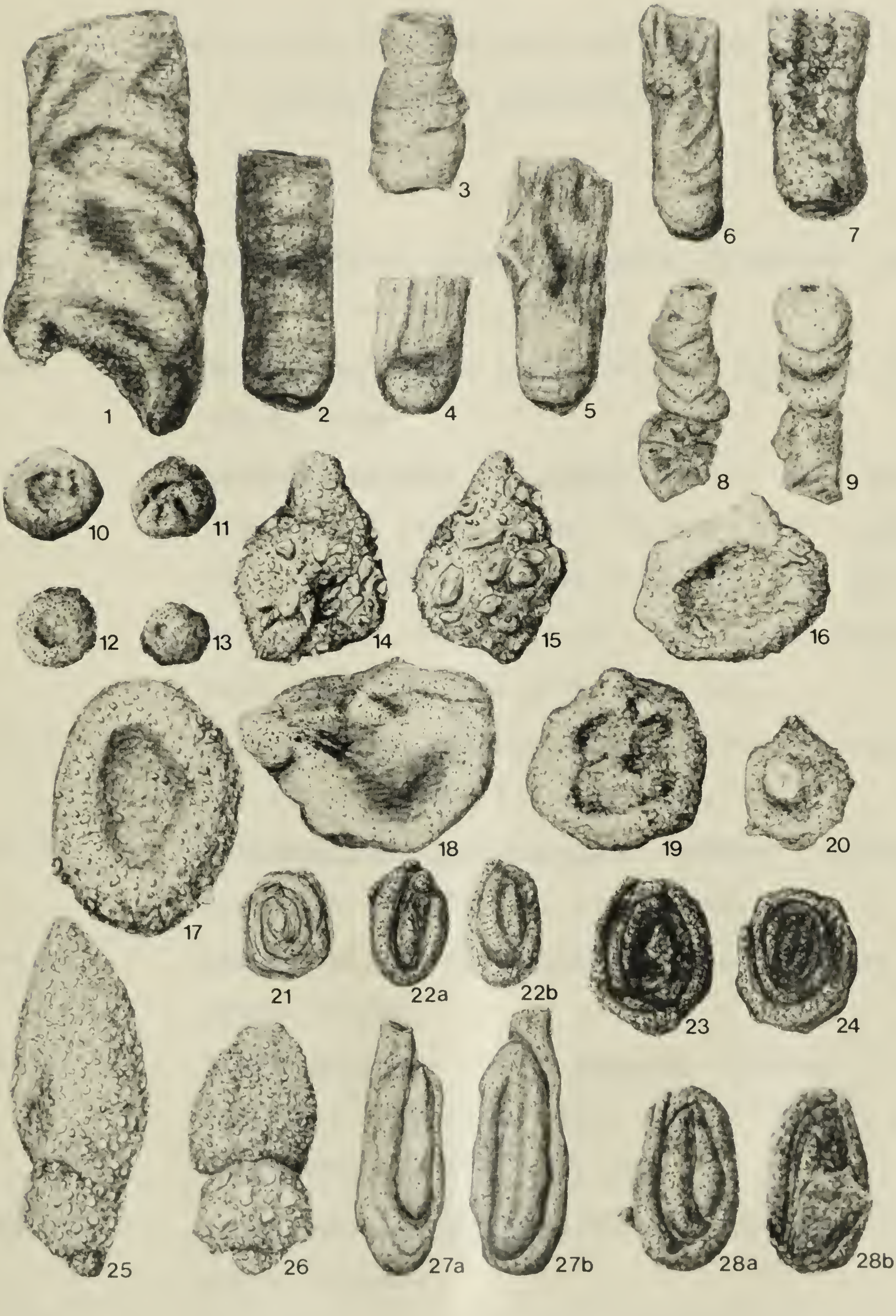
Magnification about 60X

Figures	
1	Bathysiphon vitta Nauss. Hypotype #A5.
2-9	?Hyperammina alpha. Hypotypes #C7 (fig. 2), #C9 (fig. 3), #C5 (fig. 4), #C3 (fig. 5), #C4 (fig. 6), #C6 (fig. 7), #D3 (fig. 8), and #C8 (fig. 9).
10-13	Psammosphaera sp. Hypotypes #F9 (fig. 10), #G1 (fig. 11), #F7 (fig. 12), and #F8 (fig. 13).
14, 15	Saccammina alexanderi (Loeblich and Tappan). Hypotypes #H2 (fig. 14) and #H1 (fig. 15).
16, 19, 20	Saccammina lathrami Tappan. Hypotypes #I4 (fig. 16), #I5 (fig. 19), and #I7 (fig. 20).
17, 18	Thuramminoides cf. septagonalis Chamney. Hypotypes #I9 (fig. 17) and #I8 (fig. 18).
21	Ammodiscus kiowensis Loeblich and Tappan. Hypotype #J1.
23, 24	Glomospira cf. reata Eicher. Hypotypes #J7 (fig. 23) and #J6 (fig. 24).
25, 26	Reophax cf. eckernex Vieaux. Hypotypes #J12 (fig. 25) and #J13 (fig. 26).
27a,b	Miliammina cf. awunensis Tappan. Hypotype #J34 (figs. 27a,b).
22a,b	Miliammina inflata Eicher. Hypotype #J43

(figs. 22a,b).

28a,b Miliammina manitobensis Wickenden. Hypotype #J38 (figs. 28a,b).

PLATE 8



"HASLER"

EXPLANATION OF PLATE 9

Foraminifera from the "Hasler" Section

Magnification about 60X

Figures	
1,2	*Psamminopelta bowsheri* Tappan. Hypotypes #J56 (fig. 1) and #J58 (fig. 2).
3a,b	*Haplophragmoides linki* Nauss. Hypotype #L31 (figs. 3a,b).
4-12	*Haplophragmoides* cf. *postis* Stelck and Wall. Hypotypes #K18 (figs. 4a,b), #K15 (figs. 5a,b), #K8 (fig. 6), #K9 (fig. 7), #K7 (figs. 8a,b), #K1 (figs. 9a,b), #K6 (figs. 10a,b), #K17 (fig. 11), and #K16 (fig. 12).
13, 14	*Ammobaculites fragmentarius* Cushman. Hypotypes #29 (fig. 13) and #30 (fig. 14).
15, 16	*Ammobaculites fragmentarius* Cushman variety. Hypotypes #7 (fig. 15) and #6 (fig. 16).
17a,b	*Ammobaculites* cf. *tyrrelli* Nauss. Hypotype #1 (figs. 17a,b).
18-20	*Haplophragmium* cf. *swareni* Stelck and Hedinger. Hypotypes #75 (figs. 18a,b), #74 (fig. 19), and #73 (fig. 20).
21a,b	*Pseudobolivina variana* Eicher. Hypotype #M2 (figs. 21a,b).
23a,b	*Trochammina* cf. *rainwateri* Cushman and Applin. Hypotype #N1 (figs. 23a,b).

25a,b	_Trochammina_ cf. _wickendeni_ Loeblich. Hypotype #Q11 (figs. 25a,b).
22	_Verneuilina_ _canadensis_ Cushman. Hypotype #R3.
24, 26-28	_Uvigerinammina_ _manitobensis_ (Wickenden). Hypotypes #S9 (fig. 24), #S10 (fig. 26), #S14 (figs. 27a,b), and #S13 (fig. 28).
29a,b	_Gravellina_ _chamneyi_ Stelck. Hypotype #W10 (figs. 29a,b).

PLATE 9

"HASLER"

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APPENDICES

APPENDIX A

Selected Sections

"Hasler Section"

LOCALITY 16-47-23 Hasler Formation on Hasler Creek, above grit bed horizon, Pine River area, British Columbia. Original thicknesses as recorded in feet.

Thickness	Height Above Base	Lithology of Unit
variable	287'	Overburden
5'	282'	Shale; sandy, silty, with some shaly ironstone. Suite M3793 is from the base.
6'	276'	Shale; sandy, silty, with some siltstone. Suite M3794 is from the base.
6'	270'	Shale as above. Suite M3795 is from the base.
6'	264'	Siltstone, sandy with carbonaceous material. Suite M3796 is from the base.
6'	258'2"	Siltstone, sandy.
2"	258'	Sandstone, gritty.
5'8"	252'4"	Siltstone, very sandy.
6'8"	245'7"	Siltstone, very sandy, interbedded with sandstone.
1"	245'6"	Grit, coarse.
4"	245'2"	Siltstone, black.
10"	244'4"	Conglomerate, chert pebbles, top of 16-47-24 locality section.

LOCALITY 16-47-24 Hasler Formation on Hasler Creek, below grit bed horizon, Pine River area, British Columbia. Original thicknesses as recorded in feet.

Thickness	Height Above Base	Lithology of Unit
10"	244'4"	Conglomerate, base of 16-47-23 locality section.
6'	238'4"	Siltstone, sandy with some shale. Suite M3797 is from the base.
6'	232'4"	Shale, very sandy with lenticles of argillaceous sandstone. Suite M3798 is from the base.
8'9"	223'8"	Shale, very sandy with beds of argillaceous sandstone.
2"	223'6"	Ironstone.
3'	220'6"	Siltstone, sandy and argillaceous. Suite M3799 is from the base.
2"	220'4"	Ironstone.
2'	218'4"	Shale, very sandy with thin sandstone.
4'	214'4"	Shale, dark and silty. Suite M3800 is from the base.
4'	210'4"	Shale, very silty.
2"	210'2"	Ironstone.
2'	208'2"	Shale, silty.
2"	208'	Ironstone.
6'	202'	Shale, very silty, slightly sandy. Suite M3801 is from the top of this unit while suite M3825 is from the base.
3'	199'	Shale, very silty with occasional ironstone. Suite M3826 is from the base.
5'5"	193'6"	Siltstone, shaly. Suite M3827 is from

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		the base of this unit.
3"	193'3"	Ironstone, silty (tuff-bed?).
3'6"	189'10"	Sandstone, argillaceous, shaly, with ironstone nodules in lower part.
3'	186'10"	Shale, very silty, slightly sandy. Suite M3828 is fron the base.
2'	184'10"	Shale, silty.
3'6"	181'4"	Shale, silty with 5 bands of shaly ironstone. Suite M3829 is from the base.
8"	180'9"	Shale, silty.
1"	180'8"	Sandstone, tuffaceous.
2'3"	178'4"	Shale, silty with shaly ironstone.
1"	178'3"	Sandstone, tuffaceous.
3'	175'3"	Shale, silty with thin siltstone. Suite M3830 is from the base.
6'	169'3"	Shale, very silty. Suite M3831 is from the base.
5'6"	163'9"	Shale, very silty with thin siltstone. Suite M3832 is from the base.
3"	163'6"	Ironstone, silty (tuff?).
1'4"	162'3"	Sandstone, argillaceous with siltstones.
9"	161'6"	Shale, black, silty.
3'	158'6"	Shale, very sandy with sandstone lenticles. Suite M3833 is from the base.
6'	152'6"	Shale, as above. Suite M3834 is from the base.
5'	147'6"	Shale, as above. M3835 is from the base.
5'	142'6"	Shale, silty with sandstone lenticles. Suite M3836 is from the base.
6'	136'6"	Shale, very silty with siltstone

		lenticles. Suite M3837 is from the base.
5'6"	131'	Shales, very silty. Suite M3838 is from the base.
2"	130'10"	Ironstone.
2'1"	128'9"	Shale, silty. Suite M3839 is from the top of this unit.
4'2"	124'7"	Shale, very silty with occasional sandstone lenticles.
3"	124'4"	Ironstone.
6'2"	118'2"	Shale, very silty. Suite M3824 is from the top.
6'4"	111'10"	Shale, silty with 1" band of ironstone at top. Suite M3823 is from the top of this unit and M3822 is from the base.
1"	111'9"	Ironstone, shaly.
1'2"	110'7"	Shale, silty.
1"	110'6"	Ironstone, shaly.
6"	110'	Shale, bentonitic.
.25"	109'11"	Bentonite.
1'3"	108'8"	Shale, silty with shaly ironstone at top. Suite M3821 is from the top of this unit.
2"	108'6"	Ironstone, nodules 2"X2' at 8' centres.
10'	98'6"	Shale, silty. Suite M3820 is from 5' above the base of this unit.
1"	98'5"	Tuff, devitrified and rusty.
5'4"	93'1"	Shale, silty. Suite M3819 is from the top.
4"	92'9"	Ironstone.
6'2"	86'7"	Shale, hard and silty. Suite M3818 is from 2' below the top of this unit.
4'8"	81'11"	Shale, silty with 4 bands of shaly ironstone. Suite M3817 is from 1'

		below the top of this unit.
2"	81'9"	Ironstone.
1'8"	80'1"	Shale, hard, silty.
2"	79'11"	Ironstone.
2'6"	77'5"	Shale, sandy with some ironstone. Suite M3816 is from the top.
8'4"	69'1"	Shale, sandy with lenticles of fine sandstone. Suite M3815 is from 2' below the top of this unit while suite M3814 is from 1' above the base.
1"	69'	Ironstone.
4'7"	64'5"	Shales, sandy with lenticles of fine sandstone.
2'	62'5"	Shales, sandy, interbedded with lenticular sandstone. Suite M3813 is from the base.
3'	59'5"	Sandstone, argillaceous, shaly and sandy shales.
2"	59'3"	Sandstone, crossbedded.
2'	57'3"	Shale, sandy with sandstone lenticles. Suite M3812 is from the base.
6'1"	51'2"	Shale, sandy with some .25" sandstone layers. Suite M3811 is from the base.
2"	51'	Sandstone, fine.
4'	47'	Sandstone very fine, thinly interbedded with sandy shale.
5'	42'	Sandstone as above. Suite M3810 is from the top of this unit and M3809 is from the bottom.
4'	38'	Shale, sandy with thin lenticles of very fine sandstone.
5'	33'	Sandstone, argillaceous, very shaly. Suite M3808 is from the base.
5'	28'	Shale, sandy with lenticles of very fine sandstone. Suite M3807 is from the base.

2"	27'9"	Sandstone, very fine, crossbedded.
5'7"	22'2"	Shale, sandy with thin sandstone lenticles. Suite M3806 is from 2' above the base.
2"	22'	Sandstone, calcareous.
4'	18'	Shale, sandy with lenticles of sandstone. Suite M3805 is from the base.
3"	17'9"	Ironstone, nodules 3" X 15" at 30" centres.
4'9"	13'	Shales, sandy with thin sandstone lenticles. Suite M3804 is from the base.
6"	12'6"	Shales, sandy.
6"	12'	Ironstone, nodules 6" X 12" at 4' centres.
5'	7'	Shales, sandy with 25% sand lenticles. Suite M3803 is from the base.
4'	3'	Shale, sandy with 2" of sandstone at the top. Suite M3802 is from the base.
3'	0	Shale, sandy with lenticles of sandstone.
		Water level.

"Attachie Section"

LOCALITY 77A, located on the Peace River about two kilometers downstream from the hamlet of Attachie, British Columbia. The outcrop section is a steep shale slope near a backwater on the north side of the river.

Thickness	Height Above Base	Lithology of Unit
variable	42.5m	Alluvial deposits, glacial deposits, and soils overlying decomposing bedrock. The unconformity has relief up to 5m, but is flatter a few hundred meters to the east.
7.5m	35.0	Mudstone, minor shale, 5-10% silty bands. The material is thin bedded and a white efflorescence is common. Rusty siltstone bands 10 to 20 cm. thick occur .5, 2.5, and 5.0m above the base. Suite 77A16 is from the base, 77A17 is from 2m above the base, 77A18 is from 4m above the base and 77A19 is from 6m above the base of this unit.
4.5	30.5	Mudstone with minor shale, some rusty weathering. Suites 77A14 and 77A15 are from .5 and 2.5m respectively above the base of this unit.
3.0	27.5	Mudstone, minor shale, about 10% silty bands up to 5cm Suite 77A13 is from 1.5m above the base, from a 1m band of very flaky, greasy looking mudstone. Prominent rusty weathering siltstone bands occur at 2 and 3m above the base.
3.0	24.5	Shale and mudstone, dark grey, thin bedded, weathers light grey or rusty. Suites 77A11 and 77A12 are from .5 and 2.5m above the base, respectively.
2.5	22.0	Mudstone, shale, and siltstone, with siltstone bands to 10cm thick comprising up to 25%. The siltstone is light grey to greenish and weathers rusty; bedding is laminated or medium bedded up to 10cm, faint cross bedding and undulant bedding may be present. Suite 77A10 is from 1m above the base.
3.0	19.0	Shale and mudstone; bands of silt and fine sand to 3cm, thin bedded and laminated, some faint cross bedding. Siltstone weathers rusty, fresh color is light grey; siltstone is scarce in the upper half of the unit. Suite

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		77A9 is from 2m above the base.
11	8.0	Mudstone, minor shale, dark grey in color, weathers dark grey, some rusty spots with up to 5mm vein fillings of selenite, sporadic ironstone nodules up to 20cm thick by 1m diameter, rare reddish siltstone bands, crumbly overall. Suites 77A3, 77A4, 77A5, 77A6, 77A7, and 77A8 are from .5, 2.5, 4.5, 6.5, 8.5, and 10.5m above the base of the unit, respectively.
1.5	6.5	Shale, minor mudstone, bands of ironstone nodules and siltstone layers (rusty weathering) to 4cm thick. Siltstone often crossbedded or finely bedded (1-2mm), some yellow efflorescence on shale, weathered color light grey. Suite 77A2 is from the bottom of this unit.
2.0	4.5	Mudstone, dark grey and crumbly, weathers dark grey, rusty spots with 5mm. vein fillings of selenite. Ironstone nodules 15-20cm thick occur at .5 and 2.0m above the base. Suite 77A1 is from the base of this unit.
4.5	0	Covered. Dark grey decomposed shale is visible.
		Water level.

"Farrel Section"

LOCALITY 27-131, a shale slope in the bed of a small creek entering the Peace River about 7km upstream from the mouth of Halfway River. Spot samples were taken at 5 foot intervals from the top (sample 1-1') to the base (sample 27-131'). Lithology is uniform thinly bedded dark grey to black shale. Thin silty and sandy beds are present; ironstone is rare.

APPENDIX C

This appendix is a cross-reference of thesis hypotype numbers with the samples and sections the specimens came from. A prefix of "H" designates samples from the "Hasler" section, "A" is for the "Attachie" samples, and "F" stands for "Farrel". Species and subspecies are in the same order as in Chapter 5 of this thesis. An asterisk designates figured specimens.

Bathysiphon brosgei
A-77A8: A1*, A2*, A3*, A4.

Bathysiphon vitta
H-M3826: A5*, A6-A9.

Hippocrepina sp. A
F-3: 81*, 83*, 85, 86.

Hippocrepina sp. cf. H. barksdalei
A-77A1: 89*, C1*, C2.

Hyperammina alpha
H-M3832: C3*, C4*, C5*.
H-M3826: C6*, C7*.
H-M3818: C8*, C9*, D1, D2.
H-M3800: D3*.
A-77A3: D4, D5*, D6.
A-77A4: D7*, D8.
F-4: D9*, E1.
F-5: E2*, E3*, E4-E6.

Psammosphaera sp.
H-M3820: F7*, F8*.
H-M3833: F9*, G1*, G2.
A-77A14: E9*, F1-F3.
F-26: F4*, F5*, F6*.
F-3: G3*, G4*, G5*, G6-G9.

Saccammina alexanderi
H-M3825: H1*, H2*, H3, H4.
A-77A1: H5*, H6, H7, H8*, H9.
F-3: B2*, B4*, B7, B8.

Saccammina lathrami
H-M3825: J4*, J5*, J6, J7*.
A-77A2: J1*, J2, J3*.

Thuramminoides sp. cf. _T. septagonalis_
H-M3822: I8*, I9*.
H-M3825: I10, I11.
F-5: J14, J15, J16.
F-26: I17*, I18*, I19-I21, I22*, I23*, I24-I26.

Ammodiscus kiowensis
H-M3822: J1*, J2.
H-M3832: J3.
F-1: J5.
F-3: J4*.

?_Ammodiscus_ sp.
F-1: J8*, J9*, J10, J11.

Glomospira sp. cf. _G. reata_
H-M3833: J6*, J7*.

Reophax sp. cf. _R. eckernex_
H-M3797: J12*.
H-M3834: J13*, J14, J15.
A-77A19: J16*, J17*, J18, J19.

Miliammina sp. cf. _M. awunensis_
H-M3798: J34*, J35-J37.
A-77A7: J48*.
A-77A8: J50*.

Miliammina inflata
H-M3833: J43*, J44-J47.
A-77A14: J20*, J21.
A-77A5: J22-J24.

Miliammina ischnia
A-77A3: J25*, J26-J28.
A-77A14: J29*, J30-J32.

Miliammina manitobensis
H-M3822: J38*, J39-J42.
A-77A8: J51*, J52.
A-77A7: J49.

Psamminopelta bowsheri
H-M3814: J56, J57, J58*.
H-M3800: J59.
A-77A3: J53*, J54, J55.
F-25: J63*, J64, J65.
F-27: J60*, J61, J62.

Haplophragmoides collyra
A-77A1: L1*, L2-L4.

<u>Haplophragmoides</u> <u>gigas</u>
A-77A1: L5*, L6*, L7.
A-77A13: L8*, L9*, L10-L15.

<u>Haplophragmoides</u> sp. cf. <u>H</u>. <u>gilberti</u>
F-3: L46*, L47*, L48*, L49-52.
F-23: L53, L54*, L55*, L56-L58.

<u>Haplophragmoides</u> sp. cf. <u>H</u>. <u>kirki</u>
A-77A1: L16*, L17-L20.
F-23: L26*, L27-L30.

<u>Haplophragmoides</u> <u>linki</u>
H-M3798: L31*, L32-L35.

<u>Haplophragmoides</u> sp. cf. <u>H</u>. <u>postis</u>
A-77A8: L36*, L37-L39.
A-77A2: K23*, K24*, K25*, K26, K27*, K28*, K29, K30.

<u>Haplophragmoides</u> sp.
F-10: L21*, L22-L25.

<u>Trochamminoides</u> <u>apricarius</u>
A-77A13: L40, L41*, L42, L43*, L44, L45.

<u>Ammobaculites</u> <u>culmula</u>
A-77A5: 40*, 41.

<u>Ammobaculites</u> <u>fragmentarius</u>
H-M3823: 29*, 30*.
H-M3839: 31.
A-77A2: 42*, 43-45.
A-77A5: 26*, 27, 28.
A-77A15: 25*.
F-15: 32-35.
F-23: 36*, 37-39.

<u>Ammobaculites</u> <u>fragmentarius</u> variety
H-M3825: 6*, 7, 8*, 9, 10.
A-77A2: 55, 56*, 57*, 58-60.
A-77A9: 69*, 70-72.

<u>Ammobaculites</u> sp. cf. <u>A</u>. <u>humei</u>
F-1: 11*, 12-15, 20*, 21*, 22-24.

<u>Ammobaculites</u> <u>tyrrelli</u>
F-23: 76*, 77*, 78-80.

<u>Ammobaculites</u> sp. cf. <u>A</u>. <u>tyrrelli</u>
H-M3812: 1*, 2.
H-M3814: 3-5.

<u>Ammobaculites</u> <u>wenonahae</u>
F-14: 16*, 17-19.
F-25: 46, 47*, 48-50.

Ammomarginulina cragini
A-77A3: 51*, 52*, 53*, 54.

Haplophragmium sp. cf. *H. swareni*
H-M3814: 73*, 74*.
H-M3833: 75*.

Haplophragmium sp.
A-77A1: 61*, 62-64.

Pseudobolivina variana
H-M3833: 20*.
H-M3817: M3-M6.
A-77A8: M1*.

Plectorecurvoides sp.
A-77A8: M7*, M8-M13.

Trochammina depressa
A-77A2: N7*, N8*, N9*, N10*, N11-N13.

Trochammina gatesensis
A-77A5: P1*, P2, P3.
A-77A10: P4*.

Trochammina sp. cf. *T. rainwateri*
H-M3817: N1*, N3, N4.
H-M3833: N2*, N5, N6.

Trochammina rutherfordi
A-77A1: P5*, P6-P8.
A-77A14: P9*, P10.
F-23: P11*, P12*, P13-16.

Trochammina rutherfordi s. sp. cf. *T. rutherfordi mellariolum*
F-23: 07*, 08*.

Trochammina wetteri
H-M3797: Q1, Q2.
F-14: Q3*, Q4*, Q5, Q6.
F-23: Q7-Q10.

Trochammina sp. cf. *T. wickendeni*
H-M3825: Q11*, Q12.

Verneuilina canadensis
H-M3793: R3*, R4.
A-77A5: R1*, R2.

Gaudryina canadensis
A-77A2: R5*, R6*, R7-R9.
A-77A5: R10*, R11-R13.

Uvigerinammina manitobensis
H-M3832: S9*, S11, S12.

H-M3825: S10*, S13*.
H-M3817: S17, S18.
H-M3818: S14*, S15*, S16.
A-77A3: S1*, S2*, S3-S6.
A-77A4: S7*, S8.

Verneuilinoides _cummingensis_
F-23: T8*, T9.

Arenobulimina _paynei_
A-77A19: U1*.
A-77A1: U2*, U3-U5.
F-3: U6*.

Gravellina _chamneyi_
H-M3814: W10*.
H-M3815: W11.

Gravellina sp. cf. _G_. _chamneyi_
A-77A1: W1*, W2-W4.
A-77A14: W5*, W6-W9.

Gravellina sp.
A-77A5: T1*, T2-T4.
A-77A6: T5*, T6, T7.

APPENDIX B

OCCURRENCE AND ABUNDANCE OF FORAMINIFERA FROM THE HASLER FORMATION

LEGEND

SINGLE	·	16 - 30	△
2 - 5	–	31 - 100	✱
6 - 15	+	OVER 100	◎

SAMPLES MOVING DOWNSECTION →

BATHYSIPHON BROSGEI
BATHYSIPHON VITTA
HIPPOCREPINA SP. A
HIPPOCREPINA CF. BARKSDALEI
HYPERAMMINA SP. ALPHA
PSAMMOSPHAERA SP.
SACCAMMINA ALEXANDERI
SACCAMMINA LATHRAMI
THURAMMINOIDES CF. SEPTAGONALIS
AMMODISCUS KIOWENSIS
?AMMODISCUS SP.
GLOMOSPIRA CF. REATA
REOPHAX CF. ECKERNEX
MILIAMMINA CF. AWUNENSIS
MILIAMMINA INFLATA
MILIAMMINA ISCHNIA
MILIAMMINA MANITOBENSIS
PSAMMINOPELTA BOWSHERI
HAPLOPHRAGMOIDES COLLYRA
HAPLOPHRAGMOIDES GIGAS
HAPLOPHRAGMOIDES CF. GILBERTI
HAPLOPHRAGMOIDES CF. KIRKI
HAPLOPHRAGMOIDES LINKI
HAPLOPHRAGMOIDES CF. POSTIS
HAPLOPHRAGMOIDES SP.
TROCHAMMINOIDES CF. APRICARIUS
AMMOBACULITES CULMULA
AMMOBACULITES FRAGMENTARIUS
AMMOBACULITES FRAGMENTARIUS VARIETY
AMMOBACULITES CF. HUMEI
AMMOBACULITES TYRRELLI
AMMOBACULITES CF. TYRRELLI
AMMOBACULITES WENONAHAE
AMMOMARGINULINA CRAGINI
HAPLOPHRAGMIUM CF. SWARENI
HAPLOPHRAGMIUM SP.
PSEUDOBOLIVINA VARIANA
PLECTORECURVOIDES SP.
TROCHAMMINA DEPRESSA
TROCHAMMINA GATESENSIS
TROCHAMMINA CF. RAINWATERI
TROCHAMMINA RUTHERFORDI
TROCHAMMINA RUTHERFORDI ?MELLARIOLUM
TROCHAMMINA WETTERI
TROCHAMMINA CF. WICKENDENI
VERNEUILINA CANADENSIS
GAUDRYINA CANADENSIS
UVIGERINAMMINA MANITOBENSIS
VERNEUILINOIDES CUMMINGENSIS
ARENOBULIMINA PAYNEI
GRAVELLINA CHAMNEYI
GRAVELLINA CF. CHAMNEYI
GRAVELLINA SP.

Section	Sample	TOTAL NUMBER OF FORAMINIFERS RECOVERED	FORAMINIFERAL NUMBER	FISHER ALPHA INDEX
HASLER	M3792	0067		
	M3793	0035		
	M3794	0047		
	M3795	0073		
	M3796	0034		
	M3797	0082		
	M3798	0265		3.5
	M3800	0100		2.7
	M3801	0032		
	M3825	0252		5.3
	M3826	0257		3.3
	M3827	0199		3.5
	M3828	0065		
	M3829	0034		
	M3830	0243		3.7
	M3831	0206		3.5
	M3832	0322		3.5
	M3833	0470		4.6
	M3834	0225		2.3
	M3835	0067		
	M3836	0069		
	M3837	0144		2.6
	M3839	0041		
	M3824	0094		
	M3823	0109		2.4
	M3822	0571		2.9
	M3821	0187		2.5
	M3820	0154		2.5
	M3819	0191		2.2
	M3818	0324		3.0
	M3817	0389		3.9
	M3816	0124		1.2
	M3815	0197		1.7
	M3814	0209		2.0
	M3813	0091		
	M3812	0125		1.3
ATTACHIE	77A19	0180		2.[illegible]
	77A18	0768	160	4.4
	77A17	0764	110	4.4
	77A16	0383	068	4.5
	77A15	0386	036	5.3
	77A14	0867	410	[illegible]
	77A13	0917	076	4.7
	77A12	0436	012	4.7
	77A11	0366	056	5.[illegible]
	77A10	0263	006	[illegible]
	77A09	0848	040	[illegible]
	77A08	0708	060	6.2
	77A07	0337	048	5.1
	77A06	0997	052	5.9
	77A05	1769	530	[illegible]
	77A04	0545	130	[illegible]
	77A03	1298	500	4.4
	77A02	0846	044	4.4
	77A01	0839	068	[illegible]
FARREL	01	0435		3.8
	02	0124		2.3
	03	0274		2.6
	04	0111		2.2
	05	0180		1.8
	06	0070		
	07	0001		
	08	0005		
	09	0047		
	10	0449		1.6
	11	0633		1.7
	12	0003		
	13	0013		
	14	0472		2.[illegible]
	15	0626		1.[illegible]
	16	0160		1.4
	17	0003		
	18	0349		0.[illegible]
	19	0039		
	20	0828		1.0
	21	1002		1.[illegible]
	22	0382		1.[illegible]
	23	1031		2.[illegible]
	24	0072		
	25	1080		1.[illegible]
	26	0866		1.6
	27	0681		1.4